THE

SOIL AND CROP SCIENCE

SOCIETY OF FLORIDA

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PROCEEDINGS
VOLUME 16
1956

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Sixteenth Annual Meeting of the Society

Fort Harrison Hotel

Clearwater

November 28, 29 and 30, 1956

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1957

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ACKNOWLEDGMENTS

The present volume is a record of the Sixteenth Annual Meeting of what was formerly the Soil Science Society of Florida and of the first Annual Meeting of the same organization under its new name—The SOIL AND CROP SCIENCE SOCIETY OF FLORIDA.

The Executive Committee of the Society wishes to take this opportunity to express their appreciation to the Officials of the Fort Harrison Hotel in Clearwater for the fine manner in which they cared for our every need throughout the course of the meeting; also to the officials of the Convention Bureau of the Clearwater Chamber of Commerce for the extraordinarily fine assistance they gave us with registration and other routine activities. The complete coordination of the efforts of the Hotel and of the Convention Bureau was especially helpful.

The especial thanks of the Executive Committee and of the whole Society are extended to the Chairman, to the Director, and to each member of the Governor's Water Resources Study Commission for the splendid cooperation and active assistance given in the development of a three-panel discussion of the problems of this most important field throughout Florida during the first day and evening of the Annual Meetings. Particularly do we wish to acknowledge the privilege which has been granted to dedicate this volume to our beloved Governor Collins and to the efforts and accomplishments of this exceedingly important study group which he has appointed and which is so actively engaged in this State-wide study.

The Executive Committee wishes also to express their sincere thanks to all who took an active part in the preparation of the splendid program reported in this 16th volume of the Proceedings of the Society. This, it is believed, already reflects favorably on the expanded field of subject matter provided by the change in the name of the Society reported last year.

Finally, it is the desire of the Committee, and, we believe of the whole membership, to thank the program members for their promptness in turning in their manuscripts, most of them prior to their presentation at the time of the meetings. It was through this cooperation alone that we have been able to get the Proceedings to and through the press earlier than ever before, an accomplishment which we know each member of the Society appreciates very much.

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DEDICATION

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To Governor Collins and the Florida Water Resources Study Commission, who clearly recognized the need for an over-all evaluation of Florida's water resources.

The Commission's study resulted in a broad, authoritative coverage of the salient features of Florida's water resources. The findings delineated those physical, administrative, and legal aspects which are important to the development, use, conservation, and protection of the water resources of Florida in the best interest of all the people.

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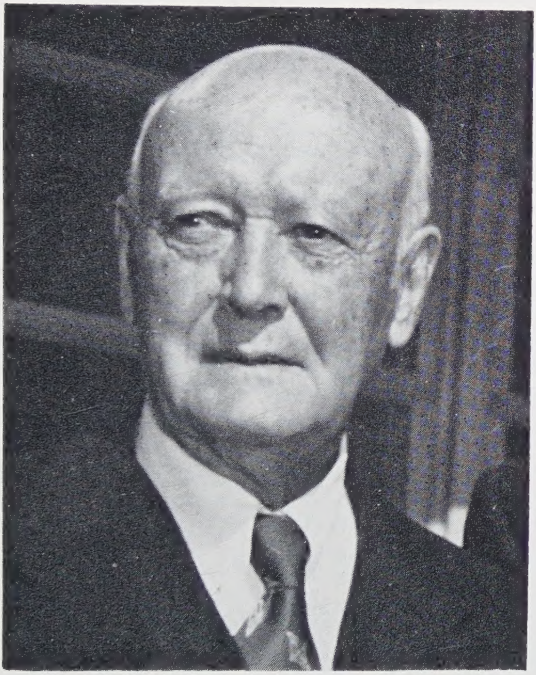

DEAN EMERITUS, DR. H. H. HUME
Honorary Lifetime Member
1956

H. Harold Hume, born in Canada, became a naturalized United States citizen in 1912. With an undergraduate degree from Ontario Agricultural College, he enrolled at Iowa State College where the B.S.A. and M.S. degrees were conferred upon him. In recognition for outstanding scientific and literary achievements, Clemson Agricultural College honored him with the degree Doctor of Science, and the University of Florida awarded the degree Doctor of Literature.

Doctor Hume began his illustrous career in Florida in 1899 as Botanist and Horticulturist at the old College of Agriculture, Lake City. After 26 years in other work, he became Assistant Director of the Agricultural Experiment Stations in 1930 and later Dean of the College of Agriculture and Provost for Agriculture. He served as Interim President of the University in 1947.

Dean Hume's prolific and factual writings have greatly enriched our storehouse of recorded knowledge on many subjects. He is world renowned as an authority on citrus culture, azalea and camellia growing, the hollies and numerous other ornamental and flowering plants.

INTERIM (SPRING) MEETING 1956

FES Field Laboratory, Hastings, March 29

Central Florida Experiment Station, March 30

MARCH 29—9:30—ASSEMBLY AT POTATO LABORATORY, HASTINGS

Discussion of Potato Diseases by A. H. Eddins; of Soil Fertility and Irrigation Problems by D. L. Myhre; Vegetable Production and Varietal Tests by E. N. McCubbin; and Potato Fertilizer by G. M. Volk.

10:30 A.M.—Tour of plots at Potato Field Laboratory

11:30 A.M.—Tour of potato farms enroute to St. Augustine via Elkton

1:00 P.M.—Lunch at Monson Coffe Shop in St. Augustine

2:00 P.M.—Travel to Sanford via Bunnell and DeLand

7:30 P.M.—Banquet at Mayfair Inn, Sanford

Mr. Randall Chase, Guest Speaker—"Sketch of the Early Vegetable Industry in the Sanford Area", Page 11.

Dr. R. W. Ruprecht—"Development of an Agricultural Research Program for Central Florida", Page 16.

MARCH 30, 9:30 A.M.

Assembly was on the grounds of the Central Florida Experiment Station to begin the program of the morning. This consisted of a review of all principal projects under way by all members of the staff under the Chairmanship of Dr. Ruprecht. Many local problems also were discussed in the field of soil fertility, irrigation, insect and disease as well as nematode control and the breeding of better vegetable varieties for local conditions.

In the afternoon there was a tour of the Station plots when there was further discussion of research findings and of the agricultural practices of the area. The Hastings and Sanford sections represent some of the oldest agricultural developments in Florida and provided a fine background for the interesting meetings that were held in this general area.

SKETCH OF THE EARLY VEGETABLE INDUSTRY IN THE SANFORD AREA

RANDALL CHASE*

In 1894 Florida was the largest citrus producing state in the union, and Sanford was the leading citrus shipping point in the State. That year Florida produced 5 million boxes, and California about 2½ million boxes. The next year the state was visited by the devastating freeze which all but annihilated the industry. The year following the freeze only 147.000 boxes were shipped. The economic results of that calamity were far reaching. Most of the orange groves were destroyed, and others almost so. Every one was poor—not just the grove owners but the merchants, the railroads, and all of the collateral economy which was dependent on citrus. People left the state, and particularly this area, by the thousands. It has been said that some of them walked out leaving many of their personal belongings, groceries, and household possessions—even dirty dishes were left. Sanford's population of 5,000 at the time of the freeze was reduced to less than 2,000. In the surrounding countryside the reduction was even greater. Those who were too poor, or loved Florida too much, to leave, then had to find new ways of making a living here. Therefore, the development of the farming and vegetable industry was a direct result of the freeze.

In the fall of 1896 the late J. N. Whitner brought some celery plants from Kalamazoo, Michigan, which he planted near his home on the St. Johns River, just north of Celery Avenue, on what is now known as Indian Mound Village. The late J. E. Pace planted head lettuce only a few hundred yards east of the Mayfair Inn, and according to the best information available, shipped some in car lots in the fall of 1897. The first carload shipment of celery—4 cars—was in 1899. This increased to nearly 8,000 cars by 1929, and has now increased to a total of about 15,000 cars per season from the state. No accurate records are available about the J. N. Whitner planting but apparently he experienced considerable difficulty. However, this did not discourage him. He accepted the challenge and continued the development of celery culture. Much credit it due to Mr. Whitner's enthusiasm, and to his determination and foresight.

The late Captain B. F. Whitner, a cousin of J. N. Whitner, planted an experimental plot of celery, about ¾ of an acre, southeast of Sanford on the prairies of Lake Jessup. In the spring of 1897 a severe freeze all but ruined this planting. The Captain considered the planting a total loss. However, after he left to attend the State Legislature, of which he was a member, the small plot of celery was cared for, damaged stalks cut off and raked away, and the plants were fertilized. The celery made a remarkable recovery and was finally harvested—being packed in tangerine boxes—and resulted in a net of about $1,300. This apparently convinced many that celery was the crop for which they were looking, because of its remarkable recuperative abilities after being badly damaged. The experiment was indeed most encouraging.

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* President, Chase and Company, Sanford, and Guest Speaker.

Shortly after, in the summer of that year, the late S. O. Chase, one of the founders of Chase & Company, made a trip to California in the interest of celery production. He received much discouragement from many of the people he interviewed but much information was gained, and, by proper evaluation of the discouraging remarks coupled with his keen sense of observation, he came back to Sanford and, with the invaluable assistance and encouragement of others, the celery industry was launched.

One of the interesting and important phases of the vegetable developments around Sanford was the system of sub-irrigation and drainage that came into use. Doctor Moore, a Methodist Minister, is credited with having put in some of the first drainage in this district. In the middle of the intersection of First Street and Park Avenue there was a fountain fed by a flowing well. In order to drain aff the water Doctor Moore made an inverted V-shaped trough of cypress boards; put it just beneath the surface, to carry the water from the fountain over to the corner and down the gutter. People noticed that this spot, on either side of the trough, was always moist and that the grass grew much better in the moist area. Mr. J. N. Whitner and other pioneers adopted this form of irrigation and drainage and applied it to the vegetable fields. Wooden troughs were later replaced with clay tile. Flowing wells, approximately 100 feet deep, were readily obtainable. Some of the earlier fields were equiped with wooden troughs, made of cypress, into which water from the flowing wells was turned. These troughs were sunk below the surface of the ground and the water from the wells seeped out and irrigated the land. During the rainy season the wells were shut off and the same troughs drained the land.

The first few years were the hardest but each year showed some increase in acreage and production. Cultural practices of the various farmers were discussed and opinions exchanged; all of which aided in overcoming the various difficulties. Chase & Company did not stand idly by in respect to the problems of grading, shipping, and marketing. About 1904 Mr. Joshua C. Chase, one of the company founders, returned from an interim period in California, to which state he went just after the devastating freeze in order to earn a meal ticket and send money back to Florida to help rejuvenate the business. He brought much valuable information that was applied to the shipping and marketing of the Florida products.

In the early days celery was often planted between lettuce; lettuce grew faster and was harvested and out of the way before the celery was too large. Most of the celery was grown from seed imported from France and was of the Golden self-blanching variety. This has practically disappeared from commercial production.

Everything was done by hand or with a mule. The first sprayers were of the knapsack type, carried on the back. Next came two-wheel carts with a pump, driven by a chain from a sprocket on the wheels; then came the power sprayer with a little motor and a larger capacity tank covering a greater number of rows. Tractors have gradually displaced mules but even now for special work some people prefer the animal to machines.

The first blanching was accomplished with pecky cypress boards 14 to 16 inches wide and about 1 inch thick. These could then be ob-

The main intersection at Park and Sanford Streets, looking south on Park in the City of Sanford in 1905. According to Mr. Randall Chase it was the submerged cypress drainage troughs installed to take care of the overflow from this central artesian well which created the idea of subsurface irrigation that has proven so important in the development of the agriculture of this section through the years. The use of cypress gradually gave way to clay tile.

tained from the mills by simply paying the loading charges and freight. Now they sell for about $175 per thousand feet, when they can be obtained. The boards were carried into the fields, generally by manpower, and placed against the stalks of celery and held in place by stakes driven into the ground. There has never been a better bleaching job than by the use of pecky cypress but the cost of the material and labor soon made it prohibitive. Next, boards were replaced by paper, treated with tar and other preservatives, which came in rolls that were put on a machine and unrolled along the sides of the celery and held in place by wire wickets. The use of paper was abandoned about 10 to 15 years ago. It was never a practice to attempt to bleach the Pascal celery which is the variety now most generally grown.

In the early days fertilizer materials were generally raw bone meal, sometimes cotton seed meal, fish scrap or guano, along with a little potash and acid phosphate. Nitrate of soda was only used sparingly. The length of time to produce a crop in early days was from 2 to 4 weeks longer than at present. Spraying practices have also gone through various evolutions. First, it was simply bordeaux spray to control blight, then others followed to control insects, worms, etc.

Packing in the early days was all done in the fields. It was a practice to remove the cypress boards, lay them flat, cut the celery, and lay it on top of the boards to keep it out of the sand. Next, the strippers took off the outer leaves and trimmed it to make a neat stalk; the packers placed it in a crate; it was nailed up and hauled to town—sometimes a distance of 4 or 5 miles—and placed in an iced refrigerator car—with no washing, no precooling and no top-icing. This method of packing was pretty generally followed until after World War I. About that time a severe infestation of celery worms occurred and arsenate of lead was used for control. Some of the celery was seized in the markets showing arsenate of lead residue and was condemned by the authorities. It was about this time that the evolution of the wash house began, which has resulted in precooling and more modern methods of packing and shipping. Top-icing came into use about this time. Wash house packing and cooling in the producing areas has largely eliminated the celery washers in the markets. Every year more of them drop out and it will apparently be only a question of time before none will be left.

About the year 1907 the farming industry was developing rapidly east of Sanford and south toward Lake Jessup. This area became known as the Sanford Celery Delta. It soon became apparent to local people that mules and wagons could not possibly haul the perishable crops, especially celery, that were about to be produced, over the many miles of sand roads for loading in refrigerated cars at Sanford. The produce needed to be refrigerated more promptly after harvesting and there were not enough mules and wagons in this part of the country to haul what was then being produced. A conference with the Atlantic Coast Line Railroad officials was arranged and they were urged to build a spur track through the Sanford Celery Delta. After their Traffic Manager and other officials had made an inspection and survey, they declined to extend their tracks, and, furthermore, made the statement that mule teams could haul everything produced for many years to come. A group of the original celery growers and developers at their own expense built a track through

the farming area. A few years later it was sold to the A.C.L. and it became the biggest producer of perishable tonnage per mile on the entire system.

During the nearly 60 years of celery production in this area, there have been failures but many have attained marked success. A few days ago one celery grower, who has been in the business 50 years, remarked that he had never failed to get his money back and sometimes he had made big money.

The foregoing comments about celery must not give the impression that it was the only vegetable grown. Quite to the contrary, the Sanford district produced car lots of lettuce, cabbage, escarole, watermelons, sweet corn, bell peppers, cauliflower, beans, squash and other vegetables. Some tomatoes were grown at one time and it is believe that in certain parts of the district they can be successfully grown in the winter. No doubt that is one of the developments for the future. One of the post-freeze agricultural activities was the growing of cassava, used for the making of starch and glue by a factory which had been built at Lake Mary, about 5 miles southwest of Sanford. This was not successful due to the fact that the season was so short and the factory could only run for a few months. This factory at Lake Mary was the beginning of the Perkins Glue Co. of Lansdale, Pennsylvania, which was later very successful and drew supplies from Java, which were available the year around.

In closing, much tribute should be paid to those hardy pioneers who, after an economic body-blow, founded a new industry which has contributed so much to this section and to the economy of Florida. It is an inspiration to realize that in the wake of a terrific disaster, which has seldom been equalled in this country, people lived, worked together, and succeeded in starting this new industry by their own ingenuity and hard work. They had no money, and practically all were heavily in debt, but they did have a will to succeed, and they were not afraid of work. No emergency loans, no production credit, or any other form of paternalism from the government was available. It was done in the original American way, in the spirit of resourcefulness and free enterprise.

Early celery growers were: H. H. Chappell, Joe Cameron, Archie Cameron, A. R. Chappell, L. A. Brumley, B. R. Brisson, T. I. Hawkins, C. F. Williams, M. J. Stenstrom, R. J. King, Mrs. B. E. Takach, A. Robbins, I. H. Terwilliger, and others.

DEVELOPMENT OF AN AGRICULTURAL RESEARCH PROGRAM FOR CENTRAL FLORIDA

R. W. Ruprecht*

Mr. Chase has told you about the beginning of farming in this area and I am going to briefly sketch the part the Experiment Station has played in this effort.

Let me preface my remarks by calling your attention to the fact that this section and the Hastings section you saw this morning are probably the oldest vegetable farming areas in the State. Practically all of our vegetable farming in this section is on what originally was classified as Leon fine sand. Those of you who are acquainted with soil classification may remember that Leon fine sand is a poorly drained soil, underlain with an extremely acid hardpan, with a pH of around 4.0. While our soils started out that way, continuous cultivation for fifty years or so together with drainage has brought about a change and they now could hardly be classified as Leon fine sand.

All of our vegetable farm land is tile drained. These tiles not only drain the soil but in times of dry weather are used to irrigate the land. This section also has been blessed with copious supplies of artesian well water. It is the combination of tiling and plentiful water supply that has made the farming of these soils feasible. This section also has the distinction of using more fertilizer per crop and per acre than any other area in the United States.

So far as I know, no experiment station work was conducted in the Sanford area until 1923 when I first came over here from Gainesville and, in cooperation with Drs. Schreiner and Skinner of the U.S.D.A. started some fertility studies on celery and Big Boston lettuce. The Bureau of Plant Industry (USDA) had a field laboratory here at that time in charge of Mr. A. C. Foster who took care of the experiments after Dr. Skinner and I put them out. These experiments were continued until 1927. The results of these experiments were published in Bulletin 218 of the Florida Experiment Station. The fertilizer formulas used in these experiments were based on Dr. Schreiner's triangular scheme. Some of you older members may remember this plan. It was widely used in all U.S.D.A. fertility studies at that time. Our experiments showed that as you go up in the N and K_2O in the formula the yield and size of the celery increased. As we increase the N and K, the P_2O_5 necessarily goes down in using this triangular system; and we ended up with a 6-2-8 formula giving us the best yield. In those days N was still reported as ammonia; so converting this to present day usage, it was about equal to a 5-2-8 formula.

Work in the Sanford area was discontinued in 1927. In 1932 a group of growers decided that they needed some further work in this area and obtained an appropriation of $5,250 per year from the 1933 Legislature

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* Vice Director in Charge, Central Florida Expt. Sta., Sanford.

to set up a field laboratory. Dr. Newell turned the matter over to me, and on October 1 Dr. E. R. Purvis, who had previously been with the Station in Gainesville and at Belle Glade and who had just received his Ph.D. degree from Rutgers University, was appointed Assistant Chemist and assigned to Sanford. Our first field plots were on the same area that we had previously used from 1923 to 1927.

One of the factors that was reducing the yield of celery at that time was "cracked-stem". We thought high salt concentrations might be the cause, but the first year none of the plots showed any cracked-stem. We did get a higher yield on the plots receiving zinc or boron. We tried some water cultures with nutrient solution and produced cracked stem with all the nutrient solutions including those to which zinc was added but not when boron in the form of borax was added. The following year all of the fertilizer plots except those where borax had been added showed the condition. Further work with nutrient solution cultures and pot cultures and field plots confirmed our belief that lack of available boron was the cause of this trouble.

Continued work with different amounts of boron showed that 10 pounds per acre of borax was sufficient to prevent cracked stem and that 15 pounds per acre could be toxic if conditions were favorable. On the other hand, we have added as much as 50 pounds without harmful results during seasons of heavy rainfall. The results of these studies were published in Bulletin 307 of the Florida Experiment Station. Further studies showed that boron applied as borax was readily leached from the soil; so there was no danger of a buildup to toxic concentrations. I am somewhat concerned about the use of some of the less soluble forms of boron that are being advocated to replace borax, especially when mixed with commercial fertilizer. We may yet end up with toxic amounts of boron. So long as you can safely prevent cracked stem by the use of 10 pounds of borax at a cost of fifty cents per acre, I say let well enough alone.

In our earlier fertilizer work from 1923 to 1927, we noted that sulfate of ammonia produced a much lower yield of celery than nitrate nitrogen or a combination of organics and nitrate. At that time we thought it might be due to the acidity produced by the sulfate. We had to close out our work before we could test this point. Because of these earlier results, we repeated these tests in 1933, but in addition to the sulfate of ammonia alone we added plots to which sufficient lime had been added to neutralize any acidity produced by the ammonium sulfate. The results were the same lower yields when ammonium sulfate was used with or without lime. To this day we still find it true, more especially on the winter crop of celery. Apparently celery just does not like the ammonia form of nitrogen.

As was mentioned earlier, one of the conditions that made the development of this area possible was the plentiful supply of artesian well water. Due to the fact that all of the water contains some salt, it was feared that the use of excessive amounts, together with the large amounts of fertilizer, might bring about a toxic concentration of salts. One of the first problems we tackled was to determine how high a salt concentration celery would tolerate. We found that celery would grow normally with a concentration up to 800 ppm of Cl. As we seldom found any soil containing more than 100 ppm of Cl, we felt there was little danger

on this score. We also made a study of the salt concentrations of a number of wells over the County. We found that the salt concentration varied from a low of about 20 to a high of 1000 ppm Cl. We also found that the salt content of each well was constant regardless of the rate of flow. Some of these wells were tested periodically over a period of six years, and we found no change in the salt concentration. Neither could we correlate the depth of the well with the salt concentrations. The depth varied from 100 to 300 feet deep. Despite the high salt concentration of some of those wells, it is seldom that we get a concentration of salts in the soil high enough to injure plant growth. In 1949, after two extremely dry years, we did get some damage which caused temporary alarm. However, after a normal rainfall the following summer, the threat vanished.

In our fertilizer studies with celery carried on through the years, we have found that the cheapest form of fertilization is an all-inorganic nitrogen fertilizer. The fertilizer people are not going to like what I am about to say, but I am convinced that you can grow celery by using only nitrate of soda potash plus some source of magnesium. In some cases you may have to apply phosphate in addition to the nitrogen and potash. At the beginning I mentioned the fact that in our early work we found a 6-2-8 fertilizer gave us highest yield. I always felt that 2 percent P_2O_5 was too low; so when we came back in 1933 we included a 5-6-8 series of plots. We obtained a higher yield with the 6 percent P_2O_5 than with the 3 percent. At present we are again conducting experiments with no P_2O_5 added. We are growing the third crop on these plots this year, and so far there is no apparent lack of P_2O_5 showing up. While this seems to contradict our earlier findings, we must consider these facts. Our early plots were on land that had not been in continuous cultivation; and, furthermore, those experiments were conducted twenty-three years ago. Applying 3 tons or more of a 6 percent or 7 percent P_2O_5 fertilizer over this length of time can build up quite a supply of this element.

In the study of minor elements, the only one that has consistently given good results has been boron. At one time we thought that a combination of zinc, manganese, and cobalt were giving a good response. While we did get a response, two years of further studies did not confirm our earlier results. Manganese gives good results where too much lime has been used or where the pH of the soil is around 7 from some other cause. Recently we have found apparent iron deficiencies in some areas. Rather than a deficiency of iron, it seems to be caused by an accumulation of copper, a result of forty to fifty years of continuous use of Bordeaux mixture. So much for soil and fertility studies. You will hear more about this tomorrow.

With increased funds appropriated by the 1937 Legislature, the work of the Station expanded and plant pathological work was begun. One of the first problems was the control of pink rot and a more effective control of early blight of celery. Despite all our efforts we have yet to find a cure for pink rot. There is one way of controlling it and that is by flooding the land for about a six weeks period. A few growers follow this practice each summer. This summer, at our suggestion, the entire area in Section 1 at Zellwood is going to be flooded for a six weeks period.

When we received a further increase in funds we enlarged our field of endeavor by the appointment of an entomologist. About this time DDT appeared on the scene, and some of the first work with DDT in this country was conducted here in Sanford with material imported from Switzerland. It was used in the control of corn earworms and cabbage worms.

In 1943 the Legislature changed our status to that of a Branch Experiment Station. At the same time we acquired a 25-acre farm. Since then our work has expanded further. Variety testing of various crops was begun in an effort to find something better suited to this area. We introduced hybrid sweet corn to replace the roasting ears usually grown. In cooperation with Cornell University and the Everglades Station, we developed a blight resistant celery, Emerson Pascal. However, it has proved more popular in Michigan than down here. Leadership on this project has shifted to the Everglades Station, as they had better trained personel in this particular field of work. However, we are still very much interested in the project and are cooperating with them in it.

In our study to control disease and nematodes in celery seedbeeds, we have continued to make progress. We have already been able to reduce the amount of seed required from 8 ounces per bed to 2 ounces and produce better plants. You will hear the latest developments on this problem tomorrow. We also have done considerable work in developing a disease resistant cantaloupe through breeding and selection. We have one variety about ready for release for local use only, as it is not a good shipper. Work is continuing, and we hope in the near future to have a variety that will prove satisfactory for shipping purposes.

In the entomological field we were among the first to realize the importance of the residue problem. At present extensive work is under way to determine the buildup in soils of various insecticides and their effect on plant growth. Work on cabbage insect control with systemics and other means and the control of corn earworm are among the important projects at the present time.

What then are our chief problems at present? Our most important problem is economic. The grower is not getting his share of the housewife's dollar. This, however, is out of our field. You may have noticed the report by Dr. Broke stating that during the last eight years the celery grower had lost money during five of them. One of our biggest problems is either to find some other crops to replace celery or to find a way to grow celery cheaper. We are working on both. Among the more promising new crops are cantaloupes. Others are onions, English peas, pink tomatoes, southern peas, cotton, and soybeans. The latter two are summer crops and would take the place of the cover crop usually grown.

Nematodes are still with us. Whether they are any worse than they were fifteen or twenty years ago is a question. Some fifteen years ago Mr. Al Taylor, who then was with the U.S.D.A. at Tifton, spent about two weeks with us studying the distribution and prevalence of nematodes. When he left, he said, "Ruprecht, by all the rules you should not be able to grow any crops because you have so many nematodes." Then came other nematologists of the U.S.D.A., and we started using DD and EDB. Still the nematodes remained while many of their predators were gone. We are still a long way from solving this problem on a field scale. However, even though we do not as yet seem able to eliminate the nematodes,

some of the materials do result in better crops. This is particularly true on seedbeds.

Weed control is being studied, especially on the muck soils in the Zellwood area where it is a really serious problem.

Liquid fertilizers are again receiving attention. Early work had indicated that their use offered no saving in cost of production. Since then the cost of these soluble materials has been reduced.

More efficient disease and insect control studies are always under way. The antibiotics are receiving more and more attention and new insecticides are always being developed.

THE INFLUENCE OF DRAINAGE AND CULTIVATION ON SUBSIDENCE OF ORGANIC SOILS UNDER CONDITIONS OF EVERGLADES RECLAMATION*

R. V. Allison**

Agriculturists working highly organic soils such as we have to deal with over vast expanses of the Florida Everglades have been conscious for a long time that you cannot drain and cultivate these soils in any normal manner and still keep them. In other words, they are something like the cake which we cannot eat and keep at the same time.

Thus, in the initial development of some of the fenlands of England we are told that the early drainage lines were dug entirely in the deep, fibrous peat that completely covered the marl beneath. In due course the marl seems to have appeared at the bottom of the canals, as they were deepened, in consequence of the steady subsidence of the land's surface. Finally, it is said, the deep blanket of organic soil disappeared entirely and farming in those areas, for many years now, has been largely in the marl which formerly underlaid the peat and in which the drainage lines now are wholly cut.

In contrast to such a situation as the British fenlands, which originally had marl under them, the greater part of the organic soils of the Everglades are underlain by lime rock that is hard and uncompromising. Around the margin of this great area the organic formation is underlain, locally, by sand or marl or the two interstratified. This, of course, constitutes quite a different situation.

The facts of these subsidence trends in our Everglades soils have been pointed out many times and in many different ways in the past, as for instance in a paper presented by the writer before the Florida State Horticultural Society in 1947 (Proceedings Volume 59: pp. 8-16). In that paper the subsidence curve shown in Figure 1, and repeated herewith, under the same number, illustrated the situation only too well, as does also Figure 2 of that paper. In the latter it is shown that during the period 1914-1943 a depth loss of as much as six feet of soil was experienced from various causes including compaction from drainage and cultivation, natural oxidation and by open fires.

According to the surface subsidence trend shown in Figure 1 it is only too obvious that the time must come when the depth of the peat over the rock will be too shallow for most cultivated crops. The most critical time will be, of course, when the depth to free soil water that must be maintained for any particular cropping operation is such that the water tables must take a position in the rock itself and the direct contact between it and the remaining muck thus largely lost. At such time as this situation

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* First presented prior to limited changes before the Organic Soils Sub-Section, Soil Science Society of America, Cincinnati, November, 1952.

** Fiber Technologist, Everglades Experiment Station, Univ. of Fla., Belle Glade.

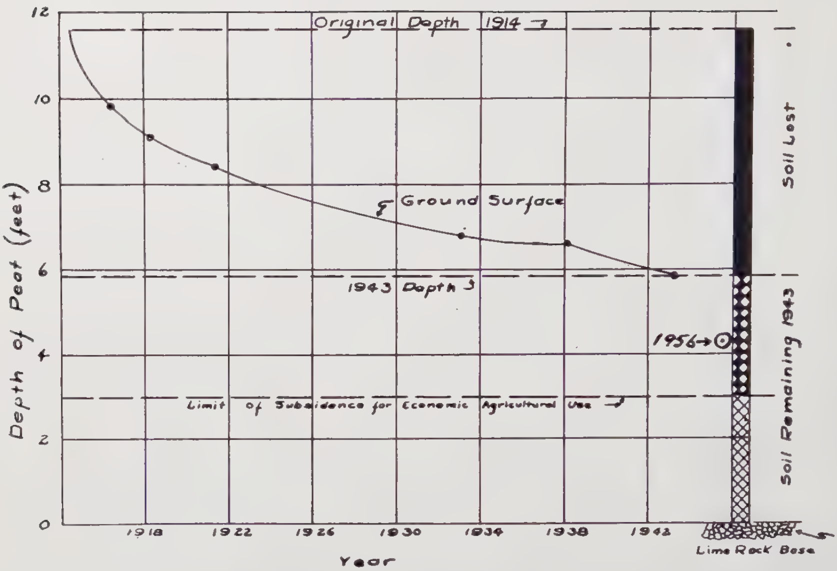

Figure 1. Graph showing rate of surface subsidence on Okeechobee peaty muck since 1914 at a location about 4 miles south of South Bay. The rather sharp, downward trend during the last few years of record shown thereon is presumably due to increased cultivation as well as the occasional fires that swept the area during the interval of those measurements. The soil depth, as of December, 1956, was 52 inches making it almost a straight line extension of the 1938-1942 segment of the curve.

Figure 2. Temporary benchmark set up about 2 miles south of South Bay at the time of the inspection trip through the heart of the Everglades which was arranged to follow the Interim Meeting of the Soil Science Society of Florida held in Belle Glade on March 17, 1943 for a discussion of Everglades problems. This shows that the ground elevation at this point in 1914, according to the best engineering data available, was nearly six feet higher than at the time the picture was taken in 1943.

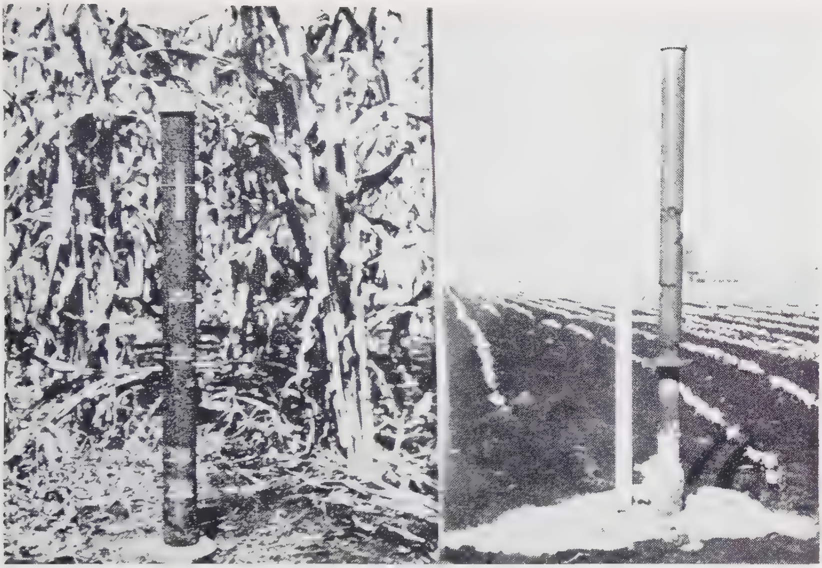

Figure 3. Benchmark originally located in the vicinity of Okeelanta on Okeelanta peaty muck which shows the subsidence of the land since 1916 to the date of the photograph, left, July, 1932 and, right, March, 1943.

Figure 4. A concrete floor slab was poured directly on the ground surface for a small building that was built at the Everglades Station in 1925. At that time the top of the slab was formed at approximately the level of the soft top soil of the adjacent area. The present photo, taken in 1952, shows a surface subsidence of about 3½ feet in 27 years. This slab is at the rear of the main building at the Everglades Station which is shown in the background.

develops other uses obviously will have to be found for this land and this area. Naturally the more diligently the planning for this eventuality is done in advance, and the more carefully it is thought out, the better the land use schedule will fit the situation when it arrives.

This irresistable trend in the subsidence of the land surface under drainage and use in the "Upper Glades" area in the general vicinity of

Figure 5. Line of labor cottages (above) shown shortly following their construction during the period 1924-26 and one of the last of them (below) in 1950 at about the time it was removed. There had been no change in the foundation in the meantime. They were simply constructed on piling driven to the rock. As in the photograph of Figure 4 and many others that could be shown, the subsidence of the land surface becomes exceedingly obvious under such conditions.

Okeelanta is clearly set forth by the bench mark shown in Figure 3 that has been used as a reference point for a subsidence line in the immediate area for a number of years. This level was established by the Drainage Division of the Bureau of Public Roads in 1916 at which time only about 18 inches of the pipe was showing above the land surface. The photo at the left in Figure 3 was taken in 1932. The latest photo of this installation, on the right in Figure 3, was taken in March of 1943 by which time more than 18 additonal inches of the pipe were exposed to view above the surface of the soil over and above that exposed by 1932. This bench mark was destroyed by field operations shortly after the photograph was taken in 1943.

Without doubt the most impressive evidences of subsidence in our organic soils are those that develop in association with buildings of one kind or another. This is probably due to the fact that we see them more often and such tendencies become more real in that relationship than in any other. At least under such conditions the obviousness of the trend can scarcely be ignored. A couple of landmarks of this nature are shown in Figures 4 and 5 with which the legends are sufficiently complete to tell the story. Both photos were taken on the grounds of the Everglades Experiment Station.

VOLUME WEIGHT AND SHRINKAGE STUDIES

In the course of early volume weight and shrinkage studies on these soils, several profiles were excavated and samples taken, in some cases all the way from the surface to the underlying rock or sand. Particular mention will be made of only two of these and of some of the values that were developed around them at that time and in the course of more recent samplings that have been made.

Profile No. 195 was first taken in April of 1929 from a typical area of Everglades peat on the grounds of the Everglades Station. At that time it showed a depth of 78 inches to lime rock. Profile No. 197 was first taken from an area of Okeechobee muck in April of 1929. This, of course, was in a position much nearer Lake Okeechobee than the Everglades peat. At the time of the first excavation of this profile the muck showed a depth of 105 inches from the surface to the rock.

The nature of the excavated profiles, and the manner in which they were taken, are shown in Figure 6 where Nos. 195 and 197 are both displayed in their desiccated form in the 6 inch x 9 inch x 48 inch heavy galvanized pans with which they were taken. The excavation of such profiles was accomplished by pressing the heavy pan into the side of a vertical cut at the position desired in relation to the profile of the soil as examined in the exposed cut. It was then dug out with a considerable over-burden at the back. The pan was then layed down flat on the ground and the overburden then carefully cut away level with the exposed edges of the pan.

The nature of the opening of the soil to rock at the time of the later (1952) sampling of the Everglades peat at the Experiment Station, Profile No. 195, is shown in Figure 7 where the surface of the soil came considerably below the level of the workman's shoulder as he stands directly on the rock upon which the total soil mantle rests.

Figure 6. Completely shrunken profiles of No. 195, Everglades peat (left) and No. 197, Okeechobee muck (right), after drying for several months in the greenhouse.

The comparative volume weight values of the soil taken at the time of the earlier samplings and others taken from November samplings of 1952 from the same locations that were represented by both profiles are shown in a somewhat graphic manner in Figures 8 and 9 where the detailed legends bring out the main points of interest in each.

If the volume weight and other values therein shown were to be fully substantiated by further samplings it would appear that the Everglades

Figure 7. The excavation shown in this photo is the 1952 examination of the Everglades peat profile No. 195. The worker is standing fully on the rock at the bottom of the pit while the bottom edge of the crossbar is exactly at land level. The average depth of the peat at this point was found to be 54 inches whereas in 1929 it was 78 inches and in 1912 it was approximately 156 inches or 13 feet.

peat profile has been somewhat more compressed by drainage and cultivation through the years since the gain in volume weight within the profile is considerably greater than it is in that of the Okeechobee muck. To be sure the weight measurements in this profile study extend much closer to the rock than the earlier ones and at that level have encountered heavier than the average materials found in the upper part of the profile.

It will be of considerable interest to follow up the above relationships in the evaluation of the comparative effect on subsidence of pasture cover and grazing and that of cultivated crops. As a result of some preliminary observations made quite recently along the line of this relationship there seems to be good reason for believing that pasture covers cause a some-

what slower subsidence of the land surface than cultivated crops. This is doubtless due to the action of one or more factors that may be active under such conditions such as: a) reduced surface temperature of the soil by the continuous shading it receives; b) exclusion of air by the firm packing it receives from tramping by animals; c) tolerance of most pasture crops of a higher average water table than cultivated crops: and d) the comparatively heavy accretion of roots and other organic residues of pasture plants through the years.

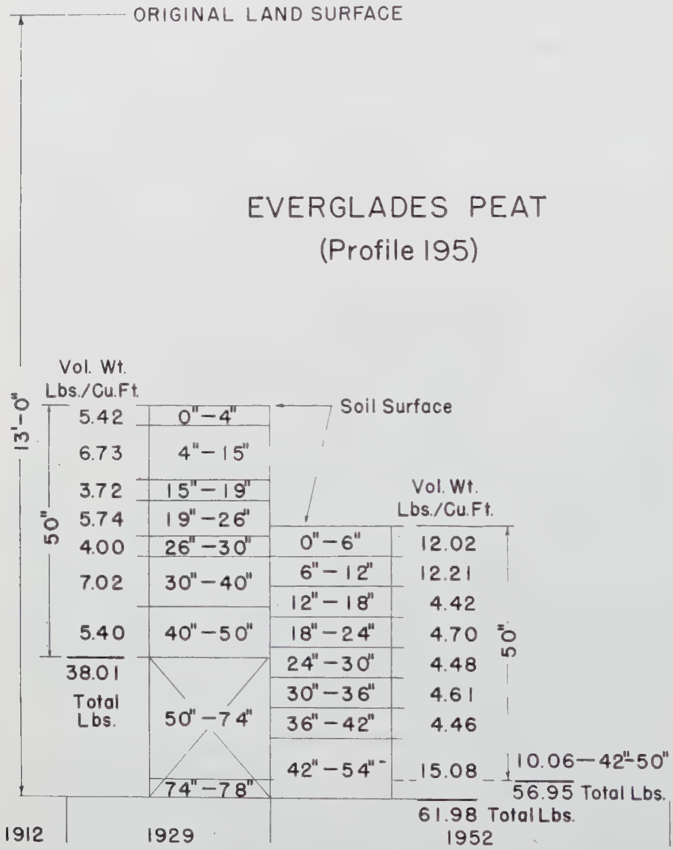

Figure 8. Comparative depth and volume weight values of the Everglades peat profile (No. 195) as studied in April of 1929 and later in November, 1952.* Note that the approximate depth of the peat in the general area of this profile in 1912 was 13 feet; in 1929 it was 6½ feet and in 1952 it was 54 inches. On the other hand, according to the volume weight values taken at different times of examination the top 50 inches of soil on a cubic foot basis weighed 38.01 pounds in 1929 and 56.95 pounds in 1952 in the lower and apparently much more compressed position that it occupied by that time.

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* The writer wishes to acknowledge the good assistance of Mr. Alan L. Craig, Soil Conservation Service (USDA), stationed at the Everglades Experiment Station, in connection with the sampling and taking of the consequent records of the 1952 excavation of profiles No. 195 and 197.

Shrinkage studies also have shown surprising results not only in relation to the amazing amount of "collapse" these soils experience upon drying but also the limited amount of reversability that takes place upon rewetting. Thus, in Profile No. 195 (Everglades peat) shown in Figure 6, the total profile that had been excavated (48 inches in depth) shrunk from an original volume of 2,592 cubic inches to 925 cubic inches or 2.8 volumes into 1. In the instance of the Okeechobee muck profile (No. 197) it was found that the same original volume of the profile as above shrunk to 882 cubic inches or 2.94 volumes into 1. Some of the strata in profiles of this nature shrank as much as 5 volumes into 1!

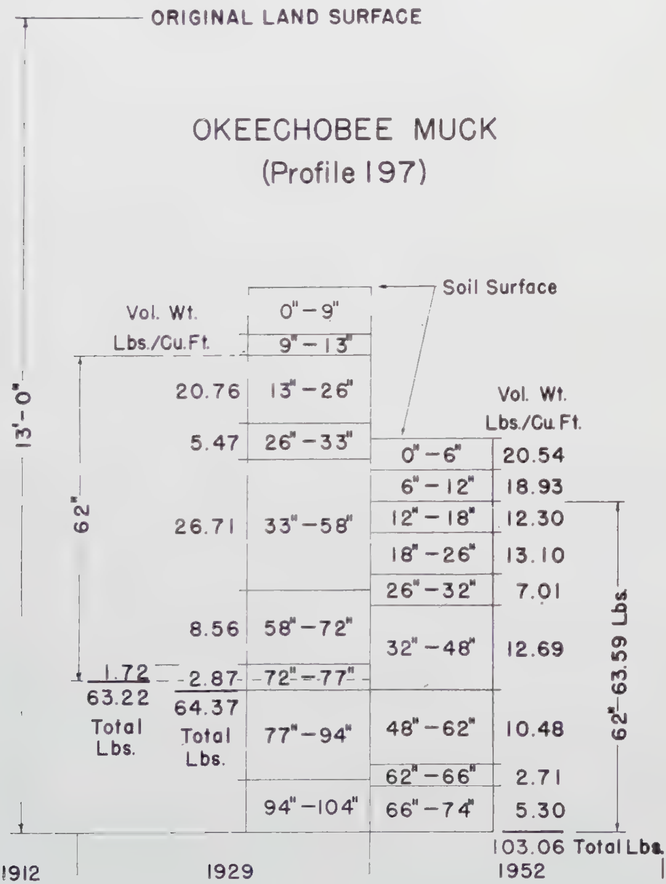

Figure 9. Comparative depth and volume weight values of an Okeechobee muck profile (No. 197) as studied in April of 1929 and later in November of 1952. Note that the approximate depth of the muck in this area in 1912 was 13 feet; in 1929 it was 8 feet and 8 inches while in 1952 it was 75 inches. Note also that a 62 inch section of both profiles, as measured from the 12 and 13 inch depth on the Okeechobee muck profiles, for 1929 and 1952, respectively, show very little difference in total weight when calculated as that cubic depth based on a square foot of surface. This is in striking contrast to the Everglades peat profile shown in Figure 7 under the same general conditions of examination.

Upon rewetting (flooding) dried soils of this nature the swelling of the material back towards its original volume scarcely ever was found to exceed a twenty percent recovery of the volume lost upon drying. This was true even after it had been soaked for as long as two months. As already noted, these profiles had only been air dried in the greenhouse but through a period of several months.

OUTLOOK FOR THE FUTURE

In view of the great water conservation and control program that is in process of development by the Corps of Engineers, U. S. Army, cooperatively with the newly created Central and Southern Florida Flood Control District the question of organic soils conservation is one of paramount importance. It was with this thought in mind that Mr. J. C. Stephens of the Soil Conservation Service, U.S.D.A., and Mr. Lamar Johnson, Asistant Engineer, Central and Southern Florida Flood Control District, reviewed all available engineering and research data on the question of organic soil subsidence under Everglades conditions and prepared a highly comprehensive report on the subject.[1] In this report it was concluded that there was grave likelihood that subsidence losses approximating one inch per year would continue though they pointed out in a cautious way that the use of the land for pasture and grazing might cause quite appreciably less subsidence than when cultivated crops are grown continuously on the same land. It is this factor of soil conservation that could be developed through the flooding of the land that would be required for this crop that has helped to stimulate interest in rice production in the Everglades during recent years.

On the basis of land levels in the Everglades known from the early records and the average annual rate of subsidence since cultivation began, Messrs. Stephens and Johnson went much further than most reports in the past on this subject by preparing soil depth lines over the agricultural section of the Everglades in what really amounted to soil depth contours and projecting these forward at ten year intervals to the year 2000. According to their calculations and tentative conclusions there will be only limited areas of organic soils in the Everglades area deep enough at that time to permit of any type of general farming. This manner of evaluation is well shown by the numerous graphs that appear in the original report at the intervals indicated, the last one showing approximately the conditions as to remaining soil depths that are expected to prevail by the year 2000.

THE EVERGLADES AS AN EXTENSIVE WILD LIFE AREA

As the use of Everglades lands for agricultural purposes approaches the sunset of their experience in this field of production there is little doubt that transition into a wildlife area of ultimate world fame will

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[1] This report served as the basis and background for a panel discussion on the general subject of Everglades Conservation, Water and Soil, that was held under the auspices of the Soil Science Society of Florida as a part of the program of its annual meeting in West Palm Beach in October 1951. The discussion is reported in full in Proceedings Volume XI of the Society, in which the Stephens-Johnson report also is published in full in the appendix.

follow, perhaps in an easy and natural manner, especially if there be a reasonable amount of preparatory planning to that end in the meantime. The most important part of that planning will be, of course, an ever enlarging program of study on the mineral soils to the east, the north and the west of the Everglades area since it is out onto these lands that the agriculture of the Glades must move as it becomes necessary for it to leave the great swampland area. It is fortunate, therefore, that a good start in the above referred to studies already has been made by the Everglades Experiment Station on the study areas that are being developed on these lands, one near Fort Pierce, the Indian River Field Laboratory, and the other near Ft. Lauderdale, the Plantation Field Laboratory.

There can be no doubt that by the end of the present century the population of the coastal areas to the east and west will be getting very heavy indeed and that the "Playground" outlook for these sections could be immeasurably benefitted by having such a huntsman and fisherman's paradise spreading out in vast proportions within the main body of the Florida peninsula at this latitude. The use of these lands for this purpose will be enormously abetted, of course, by the great amounts of residual fertilizer materials that will have accumulated in them as a result of several decades of intensive agricultural use to which they shall have been subjected by that time.

This residual fertility that will have accumulated in the soil of cultivated areas by the time the area is ready to return to swampland conditions should also do great things for the restoration and growth of the native sawgrass cover, a probability that should provide pleasant contemplation for those hardy pioneers in the pulp and paper industry who feel so strongly that this plant is certain to prove a saving source of raw material for this purpose in the future.

The importance of an extensive wild life area in this section of the State in the future is also emphasized by the rapidity with which what used to be considered readily available hunting areas in other sections of Florida are being fenced and developed for pasture and other purposes. Naturally such a rewatering of this great area should also very appreciably affect the winter temperatures of this section over and beyond what might be expected of the huge water conservation areas that are being set up at the present time to the east and southeast of the agricultural area.

It is also quite certain that demands for water will increase several times over during the next few decades in South Florida if development of population, industry and agriculture takes its natural course and is not, in fact, hampered by such a controlling influence as lack of adequate water supply. Naturally, as the Everglades returns to an essentially wild life area in the years to come, its capacity for receiving and holding water, when assisted by the water control facilities now in process of installation, would be tremendous. Such a visualization for the area in the future then, becomes simply a gradual change of duty for this great peat and muck land section of the State that will enable it to deliver a diversity of services and values which, while substantially different from the agricultural types of the present and of the immediate future, may prove to be of equal or even greater importance to the economy of the State at that not too distant time.

SYMPOSIUM: FLORIDA'S WATER RESOURCES AND UTILIZATION

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WATER RESOURCES

Wednesday, November 28—9:00 A.M.

Byron E. Herlong, Moderator *

Legal Aspects of Florida's Water Resources**

Frank E. Maloney †

As an introduction to exposition of the present water law of Florida, it is important to understand the basic differences between the eastern system of water law, sometimes referred to as the riparian system, and the western system, commonly known as the prior appropriation system. The riparian system as originally developed, and still followed in some eastern jurisdictions, holds that lower riparian owners are entitled to the full flow of a watercourse, so that upper riparian owners may not alter the flow of such a watercourse, except to make use of the water for purely domestic purposes. This rigid and antiquated system has been modified in many eastern jurisdictions by what is known as the reasonable use doctrine, under which a lower riparian owner is entitled to protection only when diversions by upper riparian owners unreasonably interfere with his use of the water. This modification allows upper riparian owners to make beneficial use and diversions to the extent that these do not unreasonably interfere with the beneficial use of others.

The western, or prior appropriation, system allows both riparian and nonriparian owners to appropriate the right to use as much water as they can successfully divert and beneficially employ, provided their appropriation is prior to that of others, in which case they gain rights, on a sort of first-come first-served basis, which may extend to complete appropriation of the available supply. Florida follows the riparian system with the reasonable use modification, insofar as water from surface water courses, including lakes and ponds, is concerned. Most western states apply the prior appropriation doctrine to ground water as well as water from surface watercourses. Many eastern states apply what is known as the English Rule, based on the concept that he who owns the surface owns to the center of the earth, and consequently has an absolute right to withdraw all of the percolating water that he can from his subsurface holdings, without regard to the effect on adjoining owners. Some eastern states on the other hand have applied the reasonable use doctrine

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* Chairman, Florida Water Resources Study Commission, Leesburg, Florida.

** Extract from "Florida's Water Resources," a report to the Governor and the 1957 Florida Legislature by the Florida Water Resources Study Commission.

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to ground water as well as surface water. Under this doctrine, no limitations are placed on the quantity of water to be taken so long as the use is reasonable, and made in connection with utilization by the owner of the surface; but if the water is to be transferred to other land, the transfer will be prevented if the withdrawal is detrimental to a neighbor's extraction and use on his own premises. As we shall see, Florida is seemingly committed to this reasonable use modification both as to ground waters and water from surface watercourses.

With this general backgound, we will now undertake to analyze the water law of Florida, first as to surface water in streams and watercourses, including man-made channels and lakes and ponds, which are treated in separate subdivisions; secondly, as to diffused surface water; and thirdly, as to ground water. The extent to which the laws of Florida recognize the interrelationships between these different categories of water will be pointed out in the following section. Next will come a brief presentation of the techniques of acquiring water rights in Florida. The concluding section will offer suggestions for modernization of Florida's water law to maximize the beneficial use of water in Florida and prevent waste and unreasonable use of this most important resource.

LAW OF STREAMS AND WATERCOURSES

The definition of a natural watercourse in Florida has developed in connection with problems of drainage, rather than in terms of use of such water. The most important case in this connection is *Davis v. Ivey*(1) in which the Supreme Court of Florida was concerned with the extent to which a railroad in traversing a natural watercourse must make provisions for the passage of water through or under its right-of-way. In this case the court adopted the following definition of a natural watercourse:

> "A natural water course is a natural stream bed having bottom and sides in which water usually flows in a defined bed or channel. It is not essential to constitute a natural water course, that the flowing should be uniform or uninterrupted. The other elements existing, a stream does not lose its character or cease to be a natural watercourse because in time of drought the flow may be diminished or temporarily suspended. It is sufficient if it is usually a stream of running water."

The court went on to hold that the railroad must provide passageway for flow like that which occurred from the heaviest preceding rain. Parenthetically, the case leaves unanswered a common problem in Florida today. Often when a railroad or road is constructed, sufficient passageway is left for a volume of water like the heaviest from preceding rain, but due to the improved drainage of surrounding land which is later brought under cultivation, the quantity of water, even from smaller rains, is such that it cannot adequately pass through the passageway provided and flood damage results to owners upstream from such passageway. In the absence of any legal solution to this problem, it is impracticable in some areas of Florida to expand water control and drainage systems upstream of such a passageway.

A riparian owner is entitled to deepen a natural watercourse in order to drain his land better, provided such deepening results only in collection of additional surface water(2). Such a watercourse can also be used for disposal of industrial waste water to the extent the stream is capable of carrying off such water without harm to lower riparian owners(3).

There is considerable law dealing with the definition of riparian land, but this law is concerned primarily with the method of acquiring title to land abutting on natural watercourses, rather than the amount of land on which water from such watercourses can be used. This leaves a serious gap insofar as the problems of irrigation are concerned, since, under the riparian doctrine, water from natural watercourses can be used only to irrigate riparian land, and under one approach a tract of land detached from a riparian tract and no longer touching on a stream loses its riparian status, and additions of inland tracts do not make such tracts riparian. A more liberal approach would allow the riparian owner to increase his riparian land in this way, while confining such riparian land to that within the watershed of the stream involved.

The Supreme Court of Florida has recognized a number of important rights as stemming from riparian ownership. Thus in *Ferry Pass Inspectors' and Shippers' Association* v. *Whites River Inspectors' and Shippers' Association*(4) the court states:

> "Among the common law rights of those who own land bordering on navigable water, apart from right of alluvion and dereliction, are the right of access to the water from the land for navigation and other purposes expressed or implied by law, the right to a reasonable use of the water for domestic purposes, the right to the flow of the water without serious interruption by upper or lower riparian owners or others, the right to have the water kept free from pollution, the right to protect the abutting property from trespass and from injury by the improper use of water for navigation or other purposes, the right to prevent obstruction to navigation for an unlawful use of the water or of the shore or bed that specially injures the riparian owner in the use of his property, the right to use the water in common with the public for navigation, fishing and other purposes in which the public has an interest."

The court has since further stated:

> "These special rights are incident to the riparian holdings and are property rights that may be regulated by law but may not be taken without just compensation and due process of law"(5).

There is a considerable body of law concerning the means by which riparian ownership can be acquired. In the case of a non-navigable watercourse, the bed of the watercourse is subject to private ownership and can be acquired by grant or conveyance. In the case of navigable streams, on the other hand, the riparian owner, in the absence of legislation, owns only to the high water mark, meaning apparently the highest point on the bank of the stream where the water in ordinary years leaves its mark on the vegetation or bank. The state in its sovereign capacity holds title to the bed of navigable waters, including the land between high and low

watermarks(6), except in cases where Spanish land grants specifically included such submerged land. The Florida Legislature has conditionally vested in riparian owners on navigable streams the title to submerged land from the edge of the channel to the high watermark, the condition being their permanent improvement(7).

From the viewpoint of this study, the most important right of a riparian owner is the right to make use of the water. There is very little general law in Florida dealing with consumptive use of water from natural watercourses, but what there is indicates an adoption of the reasonable use modification of the natural flow doctrine(8). There are provisions in the Florida statutes for erection of dams for power purposes, a nonconsumptive use(9), but there is as yet no legislation concerning the erection of such dams for irrigation or other consumptive purposes. In periods of drought such as the state is presently experiencing, numerous practical problems exist as a result of the erection of such irrigation dams. The possibility of injunctive relief against such diversions may be limited by the balance of convenience doctrine, by which other courts have restricted the use of such injunctions where the complaining party is not being substantially injured because he has no reasonable use for the water being diverted(10).

In an important case in 1927 the Supreme Court of Florida indicated that floodwaters from natural watercourses, being of no substantial benefit to a riparian owner, "may be appropriated by any person who can lawfully gain access to the stream, may be conducted to land not riparian, and even beyond the watershed of the stream, without the consent of the riparian owner and without compensation to him"(11). In Kentucky about half of the irrigators apparently use this method of acquiring irrigation water, and this Florida case may provide the legal basis for the collection and storage of excess floodwaters in the Central and Southern Florida Flood Control District. Consideration should be given to reinforcing the dictum of the Court by a legislative declaration of policy concerning such flood waters. Federal laws provide for the sale by the Secretary of the Army of surplus waters collected in this way(12), indicating that insofar as the federal view is concerned riparian owners have no right to such excess water.

Navigability and Governmental Powers Resulting Therefrom

Watercourses in Florida are navigable as far up as they may be conveniently used at all seasons of the year by vessels, boats, barges and other watercraft for purposes of commerce. Generally what constitutes a navigable river is a question of fact to be determined by the natural conditions in each case. If the stream has sufficient volume of water to float to market products of the country, it is navigable, and even if it is so shallow as to be suitable only for floating of logs, it comes within the definition(13). The essence of the definition seems to be that the watercourse must be in fact capable of navigation for useful public purposes. Such a capability, however, need not be for continuous navigation, and the court has held that a lake may be navigable even though at times large portions of it are completely denuded of water and used for harvesting crops, provided that in its ordinary state it is navigable(14).

The existence of meander lines in original surveys is an indication of navigability, but in the final analysis the real test is whether the watercourse is navigable in fact(15). Under this definition the Florida Court has indicated that the watercourse must in its natural state be capable of sustaining navigation without artificial improvement. If, however, a part of the stream is navigable without artificial improvement, the improvement of upper reaches of the watercourse by artificial means extends navigability to such areas(16).

Federal power in relationship to navigation stems from the Commerce Clause of the United States Constitution. The test of navigability for federal purposes, as for state purposes, is "Is the watercourse navigable in fact?" The federal cases seem to go further than the state cases in holding that a stream will be classed as navigable in a federal sense if by artificial aid it can be made suitable for navigation, even though it is not navigable even in part, before such artificial improvement(17). Federal power extends not only to the navigable portions of such watercourses but also to the non-navigable upper reaches to the extent that diversions there would interfere with navigation in the lower reaches(18).

A determination that a watercourse is navigable in the federal sense does not strip the state of its proprietary control over the bed of the watercourse, but does give the federal government considerable power to control the use of the water. Since practically all of Florida's navigable watercourses are accessible from other states, Congress has power to legislate concerning them, and Congress has asserted jurisdiction over the streams in the Central and Southern Florida Flood Control District for flood control purposes on this basis.

Congress may assume jurisdiction over navigable streams for the purpose of developing power, even though the latter purpose alone would not justify congressional intervention. The Jim Woodruff Dam is an example of this type of exercise of federal authority. Moreover, Congress has legislated for the prevention of soil erosion on the basis that such erosion into navigable rivers will interfere with navigation. It is on this basis that the activities of the U. S. Soil Conservation Service are justified. This legislation has culminated in the recently enacted Watershed Protection and Flood Prevention Act(19), popularly known as the Small Watershed Act, under which federal aid is given for flood control in watershed areas not exceeding 250,000 acres.

Drainage and Other Water Management Legislation

The police power and the power to act for the general welfare set forth in the Florida Constitution provide justification for numerous Florida drainage laws. The most important of these is the General Drainage Act of 1913(20), authorizing the formation of drainage districts on approval of the circuit courts of the state.

The legislature has also provided for drainage by counties(21), and for drainage of swamps and overflowed lands upon petition of the board of county commissioners of any county(22).

In addition, special legislation has been enacted for numerous counties in the state creating many types of special districts, affecting water use and control. These include drainage districts, inlet districts, im-

provement districts, mosquito control districts, navigation districts, water supply districts, and irrigation and soil conservation districts. A few of these districts, such as the Central and Southern Florida Flood Control District, are multipurpose districts, but most are limited to a single objective such as drainage, and these limitations are now creating considerable difficulty when the districts wish to undertake a different objective, as, for example, irrigation by drainage districts.

Legal problems arising from damage to natural watercourses or interference with other common law rights of riparian owners are not covered in detail in these acts, and this omission may lead to difficulties in the future, particularly since units such as drainage districts are generally looked upon as instrumentalities of the government and hence partake of governmental immunity from tort actions for damage done by them(23).

Pollution Control Legislation

Enforcement of pollution control legislation in Florida has been largely vested in the State Board of Health. Its most important weapon is the Pollution of Waters Act of 1913(24). This act forbids any deposit of deleterious substances in the waters of the state if such substances are "liable to affect the health of persons, fish or livestock." The statute covers pollution of lakes and ground waters as well as streams. Enforcement of this law is placed under the supervision of the State Board of Health. On its face the statute seems broad enough to prevent all undesirable pollution of Florida's streams, but the act has no provisions for injunctive enforcement—criminal penalties only being provided for its violation. The number of complaints concerning industrial pollution in the 1954 and 1956 state-wide problems inventories would indicate that this law as it presently exists is ineffective. In an apparent effort to plug this loophole, the State Board of Health in 1955 obtained an amendment to the chapter enumerating the general powers of the board(25). This amendment gives the board the power "to enjoin and abate nuisances dangerous to the health of persons, fish, and livestock." This amendment may prove helpful to the board in its pollution control work.

Two other general laws, an act(26) dealing with waste from mines and the new County Water System and Sanitary Financing Act(27), authorize boards of county commissioners to seek injunctions against certain types of pollution.

In connection with pollution control by state authorities, there are two Florida special acts(28) that should be commented on. By these acts Nassau and Taylor Counties are declared to be industrial counties and the acts state that it is in the interest of the public that industry be empowered to discharge sewage, industrial and chemical wastes into the tidal waters of Nassau County and into the Fenholloway River and the waters of the Gulf of Mexico, into which the Fenholloway River flows. If attacked, the legislation might well be held unconstitutional on the ground that it deprives the riparian owners on these waters of property rights without compensation in violation of the state and federal constitutions.

MAN-MADE CHANNELS

If a man-made channel has been constructed with the intention of using it permanently, and it has been used consistently with this intent for a considerable period of time, the channel will probably fall in the classification of a natural watercourse and the law stated in the previous section dealing with such watercourses will be applicable to it(29).

Assuming the channel does not fall into the classification of a natural watercourse, water in such a channel is not ordinarily subject to the usual rights of riparian ownership. Lands submerged by non-navigable waters are subject to private ownership, and if, as a result of dredging, the waters are rendered navigable, the submerged land and waters apparently remain private property(30), and the rights of an abutting owner would not be characterized as riparian.

Insofar as use of water from artificial channels is concerned, the law in Florida has not been settled, except perhaps in the case of waterways under the jurisdiction of the Central and Southern Florida Flood Control District. The legislature has expressly given the district power to regulate both the discharge into and the withdrawal from waterways within its jurisdiction(31). There is considerable legislation in Florida dealing with the construction of canals. This legislation in general stems from the provisions in the state constitution authorizing the legislature to provide for drainage of land of one person over or through that of another upon just compensation(32). Most of this legislation looks toward the solution of problems caused by too much water rather than too little. There are provisions for the use of drainage district canals for irrigation as well as drainage(33), but this legislation does not seem to address itself to the use of the water from the canals but rather provides for the use of the canals themselves to lead water into as well as out of the districts. There is little or no case law interpreting the canal legislation.

The 1956 problem inventory has indicated a weakness in the canal legislation in that it provides few if any controls limiting construction of canals or the filling in of previously constructed canals, even when these activities injuriously affect neighboring lands.

LAKES AND PONDS

Consideration of the Florida laws governing lakes and ponds is made somewhat more difficult by lack of a judicial or legislative definition of the terms, lake and pond. As defined elsewhere, the term lake is usually taken to mean a reasonably permanent inland body of water substantially at rest in a depression in the surface of the earth. Some jurisdictions distinguish between natural lakes and artificial lakes made by damning or diverting of streams, but it is not clear whether the Florida court would recognize such a distinction. Lakes are distinguished from ponds primarily because of their greater size. Legally the distinction is important only when the lake is of such a size as to be considered navigable. In general the law governing non-navigable lakes extends to and includes ponds.

If a lake is non-navigable it is susceptible to private ownership. Whether the individual lake bottom is owned privately or by the state is another matter. The 1953 Legislature decreed that submerged lands

of any nonmeandered lakes shall be deemed subject to private ownership if they were conveyed prior to 1903 by the Trustees of the Internal Improvement Commission without reservations for public use and have been taxed to the owner since that time(34). Apparently conveyances even after 1903 will have the same result under another section of the same legislation. A determination of navigability is therefore of a great importance insofar as the law of lakes is concerned.

When is a lake navigable? If it has sufficient volume of water to float products to market it is navigable as in the case of streams and watercourses. This is true even though it is so shallow it is suitable only for the floating of logs, and even though at times large portions of it are denuded of water, so long as in its ordinary state it contains water of sufficient depth for such floatage(35). In an effort to clarify the situation as to small lakes the Legislature has provided that lakes conveyed to private individuals by the United States or the State of Florida prior to 1953 will be considered non-navigable(36).

Assuming a lake to be navigable, the land appurtenant to it is classed as riparian land, and one who owns land bordering on such a lake is considered a riparian owner, providing that his title extends to the ordinary high water mark on the lake. The so-called riparian acts, under which an owner who improves the land between high water mark and the channel on a navigable stream gains title to such land, do not extend to lands on lakes in Florida, but only to lands on streams, bays of the seas, and harbors.

Use of Lakes

If a lake is non-navigable, its waters are subject to private ownership, and consequently those who own the surrounding land may not only exclude nonowners from the lake, but may also make such withdrawals as they see fit, providing all the owners can agree on these withdrawals. But if such an agreement cannot be reached, withdrawals cannot be made so as to work a detriment to others owning land on the same lake(37).

In the case of navigable lakes, the court has indicated that riparian owners may prevent the lowering or raising of the water beyond the natural limits of low and high water marks(38). The 1954 and 1956 problem surveys indicate numerous instances of individual action resulting in lowering of water levels, and this problem has become more serious during the current drought. As yet, however, no cases have reached the supreme court.

In addition to the common law right to prevent the lowering of a lake beyond the low water mark, the legislature has prohibited the drawing of water from lakes of greater area than two square miles so as to lower the level of such lakes without the written consent of all owners of property abutting upon the lake(39).

Turning to recreational uses such as bathing, fishing and boating, the distinction again must be made between navigable and non-navigable lakes. There are no Florida cases determining the rights of owners of lake-front property on a non-navigable lake among themselves. This matter could stand clarification as some jurisdictions allow each owner to boat, bathe, and fish all over the lake, while others have allowed an owner to fence off his part of the lake and exclude others from it. But

if the lake is navigable, as are most of Florida's important recreational lakes, all riparian owners and members of the public as well have the right to use the entire lake for recreational purposes.

DIFFUSED SURFACE WATERS

As in the case of so many important terms in the field of water law, apparently neither the Supreme Court of Florida nor the legislature has so far attempted to define diffused surface waters. They are generally considered to be waters resulting from falling rain or those rising to the surface in springs, which have not yet collected in a lake, pond, or natural watercourse and are still in diffused state or condition. The owner of the surface is in most jurisdictions entitled to retain as much of this water as he wishes to use himself, and to prevent it from percolating or flowing on lower land of an adjoining proprietor. Some jurisdictions have imposed a reasonable use limitation on the ingathering of surface water, but in Florida the possibility of such a limitation has not yet been discussed by the courts.

The principal diffused surface water problem with which Florida has concerned itself to date has been the disposal of such water. There are two opposed doctrines in other jurisdictions concerning the disposal of unwanted diffused surface water. Under the first of these, the civil law rule, an upper owner has an easement in a lower owner's land for drainage of diffused surface water in a natural manner. Opposed to this is the common enemy rule under which the lower owner may take any measures to keep the water off his land, even to the point of turning it back on the land of the upper owner. The Florida court has not yet expressly adopted either rule, but the decisions tend to follow the civil law rule requiring the lower owner to allow drainage of the upper owner's land(40).

The balance of convenience doctrine may be of importance in this connection as a limitation on injunctive enforcement of the civil law rule. This is particularly true where the common enemy approach is the practice in an area; for example, in areas of the Florida mucklands it is the custom for each man to protect himself from the excess surface waters as best he can(41).

The entitlement of an upper riparian owner under the civil law rule to drain diffused waters over a lower owner's land has been limited to disposal of water which would naturally flow in the direction of the lower lands. The upper owner is not entitled to gather waters which would naturally flow in one direction and divert them in another, unless the waters would have eventually found their way to the lower owner's land anyway(42).

As a corollary to the right of the upper owner to drain into a natural watercourse, lower owners on such drains or watercourses are required to keep the watercourse clear where it flows through their property to prevent the backing up of water on the upper owner's land(43).

There are a number of Florida statutes which are concerned in one way or another with the management of diffused surface waters. Most of them, particularly the earlier ones, deal exclusively with drainage or disposal of water. The general approach has been to provide for the

creation of relatively small districts for particular purposes, as for example mosquito control districts, drainage districts, and districts for the reclamation of overflowed lands. Recent flood control legislation, particularly that establishing the Central and Southern Florida Flood Control District, has taken a much broader approach through establishing a multipurpose, as compared with the single purpose district. The superiority of this multipurpose district approach should be self-evident.

GROUND WATERS

The courts have divided ground water into three categories: (1) underground streams; (2) artesian waters; and (3) percolating water generally.

Underground Streams

If the existence of a definite underground stream is established, the law with respect to surface streams, supra, is applied to the underground stream. Definite proof of the existence of such a stream, flowing in a well-defined channel, is necessary however, as there is a legal presumption that ground water is percolating water in the absence of such proof(44). This presumption greatly reduces the legal significance of this category of underground water.

Artesian Waters

Artesian waters are a type of percolating water which rise above the top of a water-bearing bed. The Florida Geological Survey is given power by statute to determine which of the water-bearing beds in Florida are a part of the artesian water system of the state(45).

Some courts have applied what is known as the correlative rights doctrine to this type of water. Under this doctrine, a landowner is limited to that portion of the available water which is proportionate to the relationship between the size of his surface area and that of the area overlying the artesian water-bearing beds. This approach has not been adopted in Florida and any legislative adoption of it would create difficult problems of administration. The factual studies reveal that a serious problem in connection with artesian water in Florida is that of waste due to unregulated flow from artesian wells. General legislation now exists in Florida, however, under which members of the Geological Survey and county sheriffs can take action to prevent this waste(46).

Percolating Waters

As was explained in the introductory section, there are three legal approaches to the withdrawal of percolating ground water. Under the first of these, the so-called English rule, the owner of the surface has an absolute right to withdraw all of the subsurface percolating water that he can without regard to the effect on adjoining owners. There is some language in earlier Florida cases which seems to support this view(47). Most western states take the opposite view, and apply the prior appropriation doctrine to ground water as well as the water in surface watercourses. Many eastern jurisdictions which originally adopted the English rule have replaced that rule with the doctrine of reasonable use which

parallels the reasonable use modification of the riparian doctrine as applied to surface watercourses. Under this theory, withdrawals of a surface owner may be limited on a reasonable use basis.

The very recent case of *Koch v. Wick*(48) aligns Florida with the reasonable use group of states. The court held that an adjoining landowner was entitled to an opportunity to show that large withdrawals from a small tract for use by the Pinellas County water works system were harmful to his land, in which case such withdrawals would be considered unreasonable and subject to injunctive sanction. It would appear from the opinion that if the use to which the water is being put is reasonable, it need not be beneficial to the overlying land, and withdrawals for reasonable uses other than on the overlying land can be made provided that such withdrawals are not in fact harmful to adjoining property owners. This constitutes a more liberal interpretation of the reasonable use doctrine as applied to ground water than exists in other jurisdictions where the use must be beneficial to the overlying land.

Salt Water Intrusion

The problem of salt water intrusion is becoming a serious problem in many of Florida's coastal areas. Legislative provision(49) for the creation of water conservation districts to combat salt water intrusion in counties of over 260,000 population should probably be broadened to make the formation of such districts possible in all coastal areas of Florida.

INTERRELATIONSHIPS BETWEEN WATER IN DIFFERENT CATEGORIES

Scientists have long recognized that water moves in a hydrologic cycle. But the historical development of different legal rules for different "types" of water reveals that the law has been slow to recognize the interrelationships between what were considered different categories of water. The common law recognized four general categories of water passing over or through lands: (1) surface water moving in a natural watercourse; (2) diffused surface water; (3) ground water in distinct underground streams; and (4) "percolating" ground water. In an early case the Florida Court expressly recognized these separate categories and also that separate classes of rights attach to the separate categories(50).

A legal approach that treats different "categories" of water in different ways can create problems for the future. Some of the stimulus behind the consideration of a comprehensive Florida water law has been the deficiencies of stream flow and lake levels during rainless periods in recent years. The stream flow and water in lakes in such periods are derived chiefly from ground water, and the state cannot therefore guarantee water to surface-water users unless it has the power to control the development and use of water from the contributing ground-water reservoirs. If the ground water is considered to be appurtenant to the land and therefore not subject to any governmental supervision or limitation as such, the surface-water users will have no recourse if ground-water development depletes the flow of the stream, as has occurred in a number of instances in Florida. In the same manner, overdrainage of diffused

surface water either by ditching or drainage wells may cause a consequent lowering of the ground-water level over a large area.

While never specifically discussing the interrelationship factor, the Florida Court has retreated in a series of steps from its earlier position of unlimited use of percolating ground waters to a reasonable use requirement(51) similar to that applied to streams and watercourses. The legislative development in this area has paralleled that of the courts. Early Florida statutes, especially those establishing water use and control districts, were generally worded so that any one district was concerned with one particular type of water and usually one type of water problem. But some of the more recent special acts of the Florida Legislature, although limited in geographic range, have shown a marked tendency toward a broader approach to water problems, with a concurrent broadening of the classes of water encompassed(52).

The developing legislative and judicial awareness of the principles of hydrology does not necessitate abolishing the recognized common law categories of water. The important factor is that the legislature and the courts recognize the interrelationship of the water in the various categories.

The extent to which future legislation is successful will depend on the extent to which the lawmakers, and the courts, are uniform in applying the same fundamental principles to all water, regardless of the paticular physical state it may be in at the moment. Whether the basic philosophy is one of reasonable use under a riparian rights doctrine, or guaranteed use under a prior appropriation doctrine, the necessity for a consistent theory applicable to all "classes" of water is inescapable.

TECHNIQUES OF ACQUIRING WATER RIGHTS

We will now consider the methods, other than by acquiring riparian or overlying land, by which one may acquire water rights. In other jurisdictions such rights may be acquired in three principal ways: (1) by grant or assignment, e.g., contract or gift; (2) by adverse use for a prescribed number of years; and (3) by condemnation.

Acquisition by Grant or Assignment

In Florida waters of a non-navigable lake are subject to private ownership. If the entire bed of such a lake is vested in one owner, it would appear that he could dispose of the waters at his will, and, conversely, that the right to such waters could be obtained from the owner by purchase or gift. If the bed of a non-navigable lake is divided so that title is in two or more owners, one such owner may not, absent agreement to the contrary, use its waters so as to work a detriment to the others(53). What he may not do himself, he may not authorize others to do by gift or grant.

Turning next to streams, the bed of a non-navigable stream is a subject of private ownership, but no Florida law was found governing the use of the waters of such a stream. Elsewhere, the use of such water is generally controlled by the same rules as are applied to use of water from navigable streams.

Navigable surface water is usually said to be the property of the public, or of the sovereign in trust for the public. Riparian owners have right in such waters but these rights, although property in the sense

that the owner may not be deprived of them save by due process of law, do not constitute a property in the water. As the Supreme Court of the United States has put it, the right is "usufructuary in character, not a right to the corpus of the water itself"(54).

For a time in Florida it was possible for a riparian owner to sever the riparian rights from the lands bordering on the water(55), conveying the one and retaining the other, or conveying to different grantees. But since 1953 this has not been possible due to the enactment of what is now § 271.09(1), Florida Statutes, 1955, which states that "Riparian rights . . . are inseparable from the riparian land." Moreover, since the Supreme Court of Florida has said that the right of an owner to use surface water is restricted to uses beneficial to the riparian land, it seems clear that such an owner cannot grant to another the right to use water elsewhere than on the riparian land.

Ground water, on the other hand, could be severed from the overlying land and sold according to the early common law. This view is on the wane in this country. The recent case of *Koch v. Wick*(56), however, seems to indicate that in Florida one may acquire the right to all the ground water he can lift, so long as the use is reasonable, by dealing with the owner of overlying land, and without running afoul of legal restrictions, as he would in attempting to acquire rights to use water from a watercourse by dealing with riparian owners.

Acquisition by Prescription

The length of time required in Florida for the acquisition of a prescriptive right has been set by the Florida Court at twenty years(57). While the case in which this was decided dealt with an access road, presumably the time period for the acquisition of prescriptive rights to water would be the same. There are no Florida statutes pertaining to prescriptive rights, nor have any cases been located dealing with the acquisition of water rights by prescription. The possibility of acquiring water rights by prescription thus is still an open question in Florida.

Acquisition by Condemnation

Condemnation through eminent domain proceedings constitutes the third technique of acquiring water rights. The Florida Supreme Court has defined eminent domain as the power vested in the state to take private property for public use(58).

Limitations on the exercise of the power of eminent domain in Florida are to be found in the Fourteenth Amendment to the United States Constitution and Section 12 of the Declaration of Rights of the Florida Constitution. These limitations provide that no person shall be deprived of life, liberty, or property without due process of law and that private property shall not be taken without just compensation.

The Florida Legislature has delegated the right to exercise the power of eminent domain to municipal water users(59) as well as to drainage(60) and flood control districts(61), so that municipal water users have the power to reach water needed for public purposes, wherever it may be in the state, through eminent domain proceedings.

Agricultural users are not in as secure a position as are the municipal users. It is as yet uncertain whether the power of eminent domain can be made available to irrigation districts in Florida. The key question is: "Would the district be condemning the rights for a public use?" Drainage districts serving limited areas have asserted eminent domain to acquire rights of way for drainage ditches and that use has been declared to be a public one by our court(62). This may augur a favorable attitude, but whether the court would also regard irrigation as a public use is as yet unknown.

The present eminent domain law of Florida is least encouraging from the point of view of the heavy industrial user whose needs cannot be filled through a public water supply system. The general legislation and the court decisions do not seem to manifest any concern over the problems of this type of user, and it seems extremely doubtful that the legislature could constitutionally authorize the use of eminent domain for such uses.

Perhaps the recognition of the desirability of large private industry by the people of the state, manifested by a constitutional provision empowering political subdivisions of the state to assert the right of eminent domain for the limited objective of securing water rights for favored industries would provide a solution to the water problems of such users.

POSSIBILITIES FOR SOLUTION OF THE LEGAL PROBLEMS

In the past Florida, along with most eastern states, has periodically had temporary excess of water, so that her problems have been problems of disposal rather than problems governing water use. With the tremendous increase in Florida's population, problems of irrigation, pollution, and salt water intrusion in coastal areas, compounded by several years of drought, have led to a re-examination of the Florida system of water law. Changes obviously should be made in the law so that the water resources of Florida may be put to the most beneficial use of which they are reasonably capable, and so that waste and unreasonable use may be minimized.

The answers to these problems must be sought through the medium of one of the two fundamental systems of water law. One possible approach is through the appropriation system of water law adhered to by 17 western states. A second approach would be to preserve, insofar as possible, the existing riparian system as developed by present statutes and case law, but with such modifications as may be necessary to maximize the beneficial use of this important resource.

A number of eastern states in the past five years have considered adopting the prior appropriation system. Legislation has been proposed in South Carolina, North Carolina, Mississippi, Arkansas, Michigan, Wisconsin, and Georgia(63). Mississippi recently adopted the appropriation system(64), and Virginia considered and rejected it(65).

Among the reasons why the majority of these states have exhibited caution concerning the appropriation system is its tendency to freeze the initial pattern of water allocation. The appropriation of entire stream supplies for irrigation in a number of western states has prevented industrial development which could produce far more wealth for the state per unit of water used than does the highly consumptive use of water for irrigation. This is especially true in arid areas. As one au-

thority has put it, "unless some adjustments are worked out in western law, western states will seriously restrict their own economic and industrial growth"(66).

The solution for the east is not necessarily the drastic legal change from the riparian system to the system of prior appropriation. The very fact that the change would be such a drastic one would create political as well as legal difficulties in obtaining passage of such legislation. This is undoubtedly one of the factors that has caused the appropriation bills to fail or be withdrawn in North and South Carolina and Michigan.

An additional factor which would militate against a change to prior appropriation in Florida is that Florida, like a number of other eastern states, seemingly regards riparian rights as property rights even though such rights are not being actually used at the moment(67). Traditional recognition of these rights gives riparian lands in Florida a value which they would not possess in an appropriation jurisdiction. A change to an appropriation system, under which all water is necessarily owned by the state in its sovereign capacity, would destroy the additional investment of riparian purchasers represented by such rights. Such a destruction, if attempted without compensation for each riparian owner, might well be held to constitute a taking of private property without just compensation, and violative of both the Florida and the United States Constitutions(68). The seriousness of this problem has been pointed out in a number of recent studies(69).

The working solution in the west has been to make more of the supply available at the time and place where it is needed. As one western authority has put it:

> "We know that the unrestricted use of the docrtine of prior appropriation has led us into trouble . . . the answer is to, by new institutions and new development, bring in supplemental water. Sometimes we can do it simply by storage, equate the flow, not really equate it so that it flows throughout the year evenly, but hold back water so that it may be delivered in the periods of time when it is needed. . . . The law of prior appropriation, with the irrigation district added on to it, and these new engineering developments, is gradually approaching then a system of equal rights and a common supply. . . . You might have an organization with taxing and bonding power to equate the flow, to take that winter storage . . . and use it when it is needed in the summer months. Maybe that is the eastern solution, and a study might very well be made then, not necessarily further study of appropriation law, but of appropriation institutions, the institutions that have been developed in the West to solve their problems(70). . . ."

Districts for water management are not necessarily appropriation institutions. The disposal of excess water through the use of such districts is a practice of long standing in Florida. Their employment for the better management of water is a presently evolving concept, and a concept which can be developed and is being developed within the riparian system itself.

A solution to the major problems in Florida would require three steps. First, insure that legal authorization exists for the capture, storage, and

use of water in excess of reasonable uses; second, authorize the diversion of such water beyond riparian or overlying land; and, third, provide means of restricting unreasonable withdrawals of water in areas where such withdrawals exceed or threaten to exceed the natural replenishment of such water, or where such withdrawals render the waters unfit for use by reason of salt water intrusion or other causes.

The realization of these steps is not necessarily through a change to prior appropriation. Legislative provisions for the first two steps, operating within the riparian system, have already been enacted in Wisconsin(71), Minnesota(72), North Carolina(73), Kentucky(74), Indiana(75), and Virginia(76). In all of these jurisdictions statutes authorize the storage and diversion of surplus water. Some of the statutes have been narrowly conceived, and permit use of this water only on riparian land(77). Limitations of this sort have been made less restrictive in some cases by liberal construction of the term "riparian land"(78).

The problem of controlling excessive diversions of surface and underground water—the third step—has likewise been the subject of eastern legislation. A New Jersey statute provides that the Division of Water Policy and Supply of the State Department of Conservation may delineate areas of the state where diversion of subsurface waters threatens to exceed the natural replenishment of such waters(79). In such critical areas permits from the division must be obtained for withdrawals of over a minimum amount allowed to take care of domestic uses. The division can refuse such permits if necessary to conserve the water in the area.

Assuming a decision to work within the riparian system of law, and to preserve, insofar as possible, the existing rights of water users in Florida as developed by our present statutes and case law, there are a number of legal problem areas where the law could be improved by a set of legal definitions clearly defining the meaning of certain terms in Florida, especially in areas where the law in other states is in conflict and Florida has not yet taken a position.

In addition, provision should probably be made for the organization and operation of new multipurpose water management districts, and for the broadening of the powers of existing districts to include the additional water management functions needed as a result of the recognition of the interrelationships between water in different components of the hydrologic cycle. It would be well to provide machinery, similar to the 1955 special legislation enacted for Leon County(80), under which boards of county commissioners would be authorized to cooperate in water management projects by using county machinery and expending county funds where the benefits of the project to the county justified such aid.

In order to best accomplish these objectives, a permanent administrative agency should be established to administer the water law of the state and to assure the fullest utilization of its water resources. The legislative process and the judicial process, which are alternatives to the administrative process, are not in a position by themselves to provide the solution to the complex problems resulting from the tremendously increased demands for water in Florida. The legislature participates in the program by determining major policy. Meeting as it does every second year, it does not have the time to handle the mass of detail, or to provide the scrutiny and consideration necessary to resolve the shifting and continu-

ing problems. It is appropriate for the legislature to establish the main outline for the new program, and leave to an administrative agency the task of developing and carrying out the detailed plans.

The courts are not in a position to investigate and supervise such a program. They are not staffed with specialists skilled in deciding complicated hydrologic problems, and they lack machinery for initiating proceedings or taking other action in the absence of a moving party. In addition, litigation in the courts is often slow and expensive, and the answers are limited to the particular issue under consideration. Court participation in the program should be based on full and adequate judicial review of the agency proceedings.

The need for continuity of attention, highly specialized knowledge in the water resources field, and speedy settlement of water rights controversies points toward the establishment of an operating agency with adequate funds and authority and the responsibility for an effective water management program for the benefit of all the people of the state.

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4. 57 Fla. 399, 48 So. 643 (1909).
5. Broward v. Mabry, 58 Fla. 398, 410, 50 So. 826, 830 (1909); See Thiesen v . Gulf, F & A Ry., 75 Fla. 28, 78 So. 491 (1918) (statements and holding to the same effect).
6. St. Anthony Falls Water Power Co. v. St. Paul Water Comm'rs, 168 U.S. 349 (1897); Shively v. Bowlby, 152 U.S. 1 (1893); See also Hardin v. Jordan, 140 U.S. 371 (1891); Fox River Paper Co. v. Railroad Comm'n, 274 U.S. 651 (1927); Appleby v. City of New York, 271 U.S. 364 (1926). But see Apalachicola Land and Development Co. v. McRae, 86 Fla. 393, 98 So. 505 (1923) (possible exceptions re Spanish Land Grants).
7. *Fla. Stat.* c. 271 (1955).
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9. Fla. Laws 1903, c. 5198, now *Fla. Stat.* § 361.02 (1955).
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29. See Stimson v. Brookline, 197 Mass. 568, 83 N.E. 893 (1908).
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35. Broward v. Mabry, 58 Fla. 398, 50 So. 826 (1909).
36. *Fla. Stat.* § 271.09 (1955).
37. Taylor v. Tampa Coal Co., 46 So. 2d 392 (Fla. 1950).
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41. Babcock v. Red Cattle Co., 6 Fla. Supp. 113 (1953).
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45. *Fla. Stat.* § 370.051 (1955).
46. *Fla. Sta.* §§ 370.051 - 55 (1955).
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71. *Wis. Stat.* § 31.14 (1955).
72. *Minn. Stat.* § 105.38-.64 (1953). For comments on the Wisconsin and Minnesota statutes see Ellis, *Some Current and Proposed Water-Rights Legislation in the Eastern States*, 41 *Iowa L. Rev.* 237, 239-41 (1956).
73. *N. C. Gen. Stat.* § 113-8.1 (1952). For a critical discussion of the weaknesses in this statute, see Ellis, *Some Legal Aspects of Water Use in North Carolina* 41-9 (Conservation Foundation, 1956).
74. *Ky. Rev. Stat.* § 262.690 (3) (1955), discussed in *Kentucky Research Publication No. 42, Water Rights Law in Kentucky* 9-11 (1956).
75. *Ind. Ann. Stat.* § 27-1403 (2) (Supp. 1955).
76. *Va. Code* §§ 62-94.1-.12 (Supp. 1956).
77. *Va. Code* § 62-94.4 (Supp. 1956).
78. Thus "riparian land" has been defined in Virginia as "land which is contiguous to and touches a watercourse; it does not include land outside the watershed of the watercourse; real property under common ownership and which is not separated from riparian land by land of any other ownership shall likewise be deemed riparian land, notwithstanding that such real property is divided into tracts and parcels which may not bound upon the watercourse." *Va. Code* § 62—94.1(5) (Supp. 1956).
79. *N. J. Stat. Ann.* tit. 58, § 4A-1 (Supp. 1955).
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Engineering Aspects of Agricultural Water Resources

HERBERT C. GEE *

The engineering aspects of agricultural water resource problems are so numerous as to require careful organization before any attempt is made to solve the water problems for a particular tract of land to be farmed. For example, the Water Resources Study Commission, created by the 1955 Legislature, has devoted the better part of a year to an inventory of the water resource problems of the State of Florida. A similar inventory should be made of the engineering problems confronting the developer of agricultural lands in this state. In the paragraphs which follow is presented a brief discussion of the major engineering problems which confront any individual engaged in large scale farming operations in the State of Florida.

SELECTION OF SITE

The agricultural economy of the State of Florida is expanding at a rapid rate. Additional acreage is being put under cultivation each year. With this expansion individual farmers are regularly confronted with the problem of selection of a site for their farming activities. All too often the site selection is made by a real estate salesman or broker who presents an attractive proposition from the standpoint of price per acre and terms of sale offered by the present owner.

The launching of a new agricultural activity, involves many important decisions. Many of these decisions cannot be made without competent engineering advice.

The basic decision concerning the property in question is the location of the property with respect to an adequate source of water supply during all conditions of weather to support the crop raising activities which the farmer has under consideration. Related considerations are existing rights of way for access to available water supply, capacity of existing canals to deliver such water to the site in question, and, equally important, capacity of these canals to remove surplus water from the area during the rainy season. Considerations of temperature in the area are important where tender crops are involved. Location with respect to large bodies of water has an important bearing upon the temperature experience of a given tract of land.

All of these basic considerations should be given thorough study before any decision to purchase a particular tract can be made. Numerous agencies in the State have available information of value to a farmer seeking a new location for his activity. Among these are the Soil and Crop Science Society of Florida, the Florida Geological Survey, the U. S. Geological Survey, the Central and Southern Florida Flood Control District, numerous drainage districts and sub-districts, the Soil Conservation Service, the State Agricultural Experiment Stations and the offices of many of the county engineers throughout Florida.

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Full utilization of available information from the above mentioned agencies, both state and federal, will result in a complete analysis of the water resource problems of the site in question and should lead to the making of a sound decision whether or not to purchase the land.

PLAN OF WATER CONTROL

Assuming the decision has been made to purchase the land for an agricultural development and the owner desires to proceed at once with the development of the property, the very first problem he faces is that of designing and constructing a suitable system of water control. An agricultural water control system properly designed in most of the area of Peninsular Florida makes provision for the removal of surplus waters during the rainy season within a sufficiently short period of time to avoid serious damage to any crops which the landowner desires to raise. At the same time, the system must be capable of reversal to deliver the quantity of water required for irrigation during the dry months of each year.

Tracts of land may be so located that one or the other of the basic operations can be handled by gravity, that is to say a tract of a relatively high ridge may be developed with safety depending upon gravity drainage alone. However, such a tract involves continuous pumping during the irrigation period of the year to insure suitable ground water condition for the production of crops. In other low lying sites, such as the lands of the Everglades Agricultural Area immediately adjoining Lake Okeechobee, it is often possible to receive a major part of the irrigation water supply from Lake Okeechobee by gravity. However, in extremely dry years even the irrigation requirements must be pumped to some of the lands.

In a two way water control system of the type normally utilized in Florida, the principal costs are incurred in providing for the removal of surplus waters during the rainy season, or the so-called flood control phase of the water year. Some systems now in existence in the Everglades area include provisions for the removal of as much as five inches of precipitation in a period of 24 hours. For large tracts of land, this runs up the cost of pumping installations and adds materially to cost of maintenance and operation.

In certain areas of the State, extensive irrigation systems are supplied water by artesian wells. In the past decade, the flow of these wells has diminished materially and in some instances the flowing well systems have been augmented either by pumping or by the supply of water from an independent surface source.

WATER QUALITY

A considerable amount of information on water quality is available in publications of the U. S. Geological Survey and the Florida Geological Survey. This information is particularly important when selecting a water source for an irrigation system. There have been instances in recent years where crops have been killed or severely retarded by the use of a source of water for irrigation with a high chloride content. Some areas in the St. Johns Basin have had this experience and during

the past year the extremely low stage of the Caloosahatchee River has resulted in intrusion of salt water all the way to Ortona Lock. This salt intrusion has rendered the river water useless for irrigation purposes.

Salt intrusion has resulted in contamination of ground water in certain important areas of Peninsular Florida. A notable example of this phenomena is to be found in Dade County where salt water moves up the coastal canals during periods of low flow, enters the porous limestone aquifer which underlies most of Dade County and contaminates the source of fresh-water utilized in shallow wells which serve a great number of private irrigation systems and are often used as source of domestic water supply. The effect of such salt intrusion will be materially reduced by the construction of gated spillways under the Central and Southern Florida Project designed to maintain a fresh-water head throughout the length of the coastal canals. Significant progress in reducing the damage from salt intrusion has already been made as a result of the construction of a few of these gated spillways along the lower east coast.

It is believed that sufficient information exists in published documents to permit any qualified engineer to determine whether or not the water supply available in most areas in the State of Florida is of suitable quality for use in an agricultural development requiring irrigation.

WATER CONTROL SYSTEM OPERATION

An integral part of the design of the system of water control for an agricultural development is an accurate estimate of the cost of maintenance and operation of such system. The operating experience of many of the drainage districts provides a valuable source of information to the engineer which can be utilized in estimating annual pumping time and hence annual fuel costs. The relationship of the water control system to any artificially regulated body of water is an important consideration in estimating annual operating costs. Obviously the on-the-land system should be designed to take maximum advantage of any existing or proposed systems of water control such as the Federal-State system of the Central and Southern Florida Project.

Cost of maintenance and operation in many water control systems is dependent upon the type of crop which the farmer desires to produce. Certain crops such as pasture grasses, are extremely tolerant of high water tables and even occasional flooding. However, the tender truck crops can stand little if any flooding and require the availability of greater pumping capacity in a given period of time to bring the crop through a typical rainy season.

Attention has been invited to the rapid depreciation of certain organic soils in Florida by the action of aerobic bacteria, burning and mechanical compaction during cultivation. Such organic soils are depleted rapidly in the region between the ground surface and the water table by the action of aerobic bacteria, the same bacteria which operate in the trickling filter of a conventional sewage treatment plant. The loss of soil to these bacteria can be materially reduced by maintaining the highest possible water table which the crop being raised on the land will tolerate. The life of the land can be prolonged by maintaining it in "flood fallow" between crops. An extensive acreage of celery land is placed in flood fallow each year in the vicinity of Lake Apopka in Orange County.

CONCLUSION

From the foregoing paragraphs, it is apparent that the farmer in Florida is almost continuously confronted with a number of very important engineering problems having to do with water and its removal from or delivery to his developed land. The advice and assistance of competent engineers experienced in the field of agricultural water control are required to assist the farmer in selecting a suitably located tract, in designing and constructing a system of water control and in maintaining optimum conditions for crop production.

Ground Water as a Resource in Florida's Agriculture

ROBERT O. VERNON *

INTRODUCTION

We are discussing a substance here today that is composed of two poisonous gases, combined under atomic stresses in the atmosphere. The fluid is a transparent, odorless, tasteless, colorless compound composed of two volumes of hydrogen and one of oxygen or by weight; two parts of hydrogen and sixteen parts of oxygen, with the symbol of H_2O. It solidifies at 32 degrees F. to form a solid and boils under normal atmospheric pressure at 212 degrees F., forming steam.

Water is probably the cheapest, most valuable, and least valued natural resource in the State, being mined and delivered to your door for about ten cents per ton. Life would be impossible without water, as all living matter requires it in daily metabolism. Tissues are bathed in aqueous solutions containing life sustaining substances. Plants, like all other living matter, are composed of more water than of solids. As an average, for each pound of solid matter, plants contain five to ten pounds of water. In the growth period during which this pound of solid was synthesized by the leaves or captured in solutions by the roots, several hundred pounds of water may have been used to transport sugar and other compounds from the leaves and minerals from the soil to the leaves and there evaporated. The mechanism of such evaporation is called transpiration.

During the past few months we have heard many statements about the water situation in Florida. These have varied from, "Florida will be a desert by 1976 unless . . ." to "The State has in storage from four to six times the amount of water present in the Great Lakes." It is entirely true that Florida occupies the same latitude as the Great Sahara, and with a complete reorientation of our topography, temperature gradients, and a change in the paths of air masses, the State's water resources could dry up.

Florida has about 57,000 square miles of area, part of which is underlaid by salty water; the Great Lakes cover about 94,000 square miles, and it is estimated that there are more than 5,000 cubic miles of water stored in the lakes. No estimate of the large quantities of water stored in the ground around the Great Lakes is attempted.

If we presume that all of Florida is underlaid by fresh water and that the average ground water head is 65 feet, it can be computed that 57,000 square miles are underlaid by 2,600 feet of fresh water or a column of about one-half mile. Therefore, there is a section of rock 28,500 cubic miles under the State that contains fresh water. Since this rock has an average porosity of 20 per cent, it must follow that there would be a maximum of 5,700 cubic miles of fresh water present, if all salt water is discounted.

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The State's water situation lies between the two extremes given above. The State stands at the top in the Nation in water resources, being blessed by an abundant rainfall. There are adequate supplies for both additional industry and agriculture. The water is sweet, pure and potable, requiring as a rule no treatments except for normal health precautions. It is true that in a few areas some trouble is experienced in obtaining water because of scattered surface supplies or of low formation yield and that some areas along the coast have not spaced wells wisely and have withdrawn water from the aquifer too rapidly, allowing salt water from the ocean to contaminate the well fields. Some of our rocks contain entrapped salt water which may be flushed out in wells and, in addition, the levels of ground water in wells have been decreased in some areas because of overdevelopment. A wise and controlled usage is strongly recommended for these areas, but elsewhere there is an abundance of water. Our problem is, generally speaking, getting water to the place it is needed at the time it is needed.

Our wealth of water is obtained entirely from a rainfall that averages about 53 inches annually over the State. This rainfall is the income upon which the State has to live. If more water is used than falls on Florida, a draft must be made on the water stored in the lakes and underground formations, our savings account, and when this is exhausted, the State is bankrupt.

The State, except for a portion of the Panhandle and the northern Peninsula, does not depend for its water supply upon any rain that falls on other states. Certainly, none of our water comes from West Virginia and other northern states as has been reported. The Peninsula, south of Marion County, must depend entirely upon the rain that falls upon the Peninsula. The responsibility of how we use the water, whether wisely or unwisely, rests directly upon the citizens of the State.

Hydrologic Cycle: Water is in constant movement upon, in and above the earth. It is easily converted to gas by normal heat of the sun and earth, rises into the atmosphere and with height cools to water droplets to form clouds. These move in general from west to east. Further cooling may form drops of water too heavy to be held up by convection currents and rain or other precipitation may result. Where this rain falls upon land, part may collect upon or run off of the surface, part may enter the ground, part may be evaporated and part may be used by plants and transpired. This process is continuous and is called the hydraulic cycle. All of the water moving upon the land surface is known as surface water, the water contained in voids of the rock underlying the ground surface is called sub-surface water.

Surface Water: Surface water merges with ground water and hydrologically they are closely related, being in some cases indistinguishable, such as at spring orifices. Surface waters are commonly contained in well defined channels such as rivers, creeks, lakes, sinkholes and ponds, or in more poorly defined sloughs, marshes, swamps and everglades.

Florida is well known for a karst topography, marked by sinkholes, often lake filled, and streams are at a minimum, but about 50 drainage basins drain the State. The St. Johns, Suwannee, Kissimmee, Oklawaha, Withlacoochee, Apalachicola and Choctawhatchee are the larger rivers. The southern Peninsula has few well defined drainage basins, the divides

being almost indistinguishable. Water fills the marshes and everglades and stands in shallow sheets or moves slowly toward the tip of the Peninsula, aided and accelerated by drainage canals. A former tendency toward excessive drainage and loss of organic soils by oxidation is now being controlled by drainage districts.

The canals through the Everglades, the St. Lucie Canal and the Caloosahatchee River, are the principal controls of Lake Okeechobee; the lake occupies an area of 700 square miles and is the largest fresh water lake within the boundaries of one state.

Florida claims more named lakes than any other state, estimates running as high as 30,000. Some of the largest and most beautiful in the State are Apopka, Blue Cypress, George, Istokpoga, Orange, Crescent, Dora, Eustis, Griffin, Harvey, Monroe, Kissimmee, Poinsett, Trafford and numerous others.

The greatest yield from the various watersheds of the Peninsula occurs in the fall and the least comes in early summer. In the Panhandle, water distribution is the same as for bordering states, the high water coming in the winter, the low in early spring. The yield parallels the rainfall of the area.

Florida is in an enviable position in water resources because the runoff, or discharge from surface waters, is more uniform than that of other states. Most water uses are gauged to the minimum available and stream runoff varies in the State from one-half to two times the average, whereas streams of other sections vary from one-fourth to four times the average.

Florida also compares favorably with the United States as a whole in annual precipitation and runoff. The estimate for the United States is about 30 inches of precipitation and 9 inches of runoff, whereas Florida has an annual rainfall of 53 inches and 14 inches of runoff. This runoff includes ground-water discharge into springs, but does not include direct seepage and spring flow into the ocean, a sizable amount. The rainfall less the runoff gives some measurement of the amount of water lost to evaporation and transpiration, something less than 39 inches.

Some idea of the amount of water that can be safely used without danger of exhaustion is obtained from runoff figures. Florida uses over two billion gallons of water daily. A runoff of 14 inches is about 40 billion gallons of water per day. It can be seen that the State can safely develop a water use of about 20 times that currently being used, provided such use is evenly distributed with the supply.

Subsurface Water: All of the natural water contained in the voids and interstices of the rocks below the land surface are called subsurface waters, regardless of their origin. This includes soil moisture, water in the capillary voids, water moving from the land surface to the top of the ground-water level that marks the top of saturation of all the voids in the rocks; and this water as it moves laterally and vertically to the ground surface emerging as seepages and springs.

One classification of subsurface water would include a zone of aeration and a zone of saturation as the two large physical divisions of subsurface water, the separation being made at the water table below which all of the permeable interstices are filled with water and above which the interstices contain both water and air. The water table and all water

levels, for all practical purposes, are controlled by the algebraic sum of rainfall, transpiration, evaporation, seepage and runoff.

The zone of aeration is separable into three sub-zones: the belt of soil water, the intermediate vadose belt and the capillary fringe belt. The belt of soil water is the upper zone from which water is discharged into the atmosphere by plant transpiration and by evaporation. This is the zone that you, as agronomists, find the most interesting. Most subsurface water passes through this zone into the intermediate vadose belt beyond recall by the roots of plants, on its way down to the zone of saturation. In order for plants to obtain the use of this water once it has passed the soil belt, it becomes necessary to mine it and place it back on the surface for reentry into the soil. There are large quantities of water in dead storage in the vadose zone, either sinking slowly downward drawn by gravity to the underlying zone of saturation or drawn by molecular attraction into the capillary fringe. The thickness of the capillary fringe belt may be several feet in fine grained clastics and it can be identified in wells because the walls are noticeably wet through the belt, but no water is delivered into the well until the water table is penetrated.

That portion of the subsurface water named the zone of saturation, where all the pores of the rock are filled by water is also called ground water and the upper surface of saturation is called the water table. There are many occurrences where a belt of saturation may exist, held by an impervious layer, perched in the zone of aeration, with a second water table below it; in which case it is a perched water table. The lakes of Orange, Leon and numerous other counties are perched waters. This belt more commonly is a uniform zone of saturation filling all of the interstices of the rock from the base of porosity, deep within the earth, upwards to the water table. The surface of the water table conforms rather generally with the configuration of the earth surface, and generally the water table intersects the water levels in streams, ponds and lakes. Where the water table is free to rise and fall with rainfall and is not confined, it is said to be under water-table conditions.

In some cases the ground water may fill interstices in rock that lies below a relatively impervious formation, called an aquiclude, being trapped below this. The water table may be higher in some parts of such an aquifer than in others, in which case the water is under pressure and is said to be artesian.

A knowledge of the depth to the water table is important since it determines the depth of wells, the setting of pumps and when measurements of the elevations of the water table are referred to sea level and plotted on a map they provide a reliable method of determining the direction of flow, areas of recharge, areas of discharge, and they assist in the solutions of ground water problems. Ground water is the intermediate coarse of rainfall traveling through the earth to its eventual destination—the sea, and the zone of saturation forms a series of huge reservoirs that contribute water to natural surface drainages and which can be tapped by wells.

In Florida about 93 per cent of the ground water used in agriculture, industry, municipal and domestic supplies is derived from artesian waters. Therefore, much of the remainder of this discussion will be on artesian waters.

THE FLORIDAN AQUIFER: The State is blessed by having one of the most permeable and prolific artesian aquifers in the world, from which most of Florida's water supply is derived. The Floridan aquifer, the name applied to this large artesian reservoir, includes limestones of Cretaceous to Miocene ages that are the subsurface formations beneath the southern portions of South Carolina, Georgia and Alabama, and all of Florida except possibly for the westernmost Panhandle. The formations yielding these copious supplies of potable and high-quality, ground water, underlie these states to depths of several thousand feet. At some places the formations making up the aquifer are exposed, but generally the top of the aquifer lies several hundred feet beneath the ground surface. Along the Ocala uplift, striking northwest-southeast in the western part of peninsular Florida, and in Jackson and adjacent counties of Panhandle Florida, the formations making up the aquifer are generally exposed. A sharp escarpment marks the limits of the aquiclude around the Ocala uplift and in Panhandle Florida and can be seen west of Gainesville.

The formations composing the Floridan aquifer are known to extend to more than 5,000 feet in some parts of Florida and cavities in limestone have been recorded at depths greater than 8,000 feet, but there they are filled by salt water. The aquifer is composed principally of a large porous mass of limestone, with horizontal permeability much greater than that of the vertical. For simplicity, let us visualize that in this porosity there has been developed over geologic time a large bubble of fresh water and, along the coasts and in the southern Peninsula, heavily mineralized water under artesian pressure. This bubble of artesian water is floating upon salty water, in part more saline than sea water, and the shape of the bubble is bi-convex, the altitude of the top surface governing the altitude of the bottom surface. In general, the depth at any point on the land surface to the fresh water-salt water contact is approximately 40 times the ground-water level or artesian pressure measured at that point expressed in feet above sea level.

In Polk County and in other areas to the north, sinkholes formed by the collapse of solution channels in the limestone have displaced the Hawthorn, creating channels through which recharge may occur at high land elevations. The recharge in Polk County, for example, has built up the piezometric surface to the north and south. Water, therefore, moves down the slope of the piezometric surface across formation boundaries to supply the copious flow of springs and discharge to wells.

One noteworthy result of the relationship of discharge to recharge in the artesian system is the difference in artesian pressure at different depths.

In an area of recharge, water levels are generally higher in the upper limestone formations than in the lower ones. In discharge areas, the converse is true. That is why in Levy County, an area of discharge, deeper wells will flow, whereas shallower ones will not.

THE PIEZOMETRIC SURFACE: The shape of the mass of artesian water can be visualized by studying a piezometric map made up of lines that connect points of equal artesian pressure as measured in wells that penetrate the Floridan aquifer. It is constructed by measuring the water levels or pressures and converting these to heights above sea level and locating the position of the well accurately upon a map of Florida. Smooth lines running through points of equal pressure complete the map. A map of

the elevations on the water table or of the artesian pressures is fundamental to determining the basic water facts of any area.

The map of the piezometric surface of artesian water in Florida is not the same as the water table, which is, as previously noted, the upper surface of the zone of saturation. The piezometric surface exists only in scattered wells that penetrate the artesian aquifer and in the imagination of those who work with it. Although largely imaginary, it has a very material significance. It represents the height to which water will rise in wells that penetrate the artesian limestone formations in Florida.

The piezometric map is an aid in determining the direction of flow of the artesian water through the aquifer which acts as an effective conduit over all of Florida. In those areas, such as the center of Peninsula Florida, where the contours are high, it can be assumed that water is entering the aquifer and is flowing down gradient from that area to areas where the contours are low. Heavy discharge is occurring along the valleys, saddles and low places in the piezometric map. Most of the large artesian springs of Florida are located in the saddle that crosses the Peninsula just north of the high Polk County recharge area. Please note the large valley made in the piezometric surface that extends up the valley of the Suwannee River. All along this river numerous artesian springs are discharging water into the valley.

Entering the aquifer at recharge areas, the water may pass beneath the impervious beds of the aquiclude which confines the water under hydraulic head as it moves down gradient in the aquifer. In areas where the ground surface is lower than the piezometric surface, the water will have sufficient head to flow from wells that puncture the confining beds and penetrate the aquifer. Flowing wells can be obtained over about one-third of the State generally along coastal areas and extending into stream valleys.

Springs: Florida has seventeen first magnitude springs (a flow of 64.6 million gallons per day or larger), more than any other state or foreign country. At least 100 named springs are known, most of which are fed by artesian water. It is interesting to consider for a moment what about these springs might interest various professions; the water works supervisor, for example. The mean flow of Rainbow Springs over the last fifteen years has been about 700 cubic feet per second. That amounts to about 450 million gallons of water daily. The City of Miami uses about one-eighth of that amount, and the spring could supply one-half of the industries and municipalities in Florida. It would just about supply drinking water for all the people of the world.

A geologist might be more interested in another feature of the spring—its function as an excavator. We are all familiar with the role played by the solution of limestone in the development of Florida geology. We are inclined to view the solution process as an extremely slow one, as, of course, it is. However, the quantities of limestone carried away by solution in our larger springs is apt to be surprising. For example, 140 tons of limestone is removed by the water from Rainbow Springs in each 24-hour period. Three times this much—450 tons a day—is carried away by Silver Springs, not because the flow is much greater, but because the water is harder. Stated differently, 450 tons of limestone would fill a room 30 feet long, 20 feet wide, and 10 feet high and

over a period of ten years, the limestone would cover a square mile of area to a depth of one foot.

Quality of Water: Deep wells drilled for oil have generally penetrated very salty water over most of the State. This water is commonly much saltier than sea water and from these scattered records, it has been inferred that the entire State is underlaid by these heavily mineralized waters and that the fresh artesian water is floating upon the salty water.

During the geologic past, sea water has covered Florida many times and under the pressure of the raised water level salt water has permeated the limestones underlying the State. Some hydrologists believe that much of the artesian aquifer is salty because of these invasions of sea water and that this salt water is now being flushed out of the aquifer by high hydraulic pressures of fresh water built up in recharge areas of the artesian system. Presumably with time all of these entrapped salt waters will be flushed out and the entire aquifer will contain fresh water.

Commonly the ground water closely adjacent to the water table is soft and may contain some iron, but where the aquifer is limestone, the water is harder, but never as hard as artesian water from the Floridan aquifer. Local artesian aquifers in Panhandle Florida are, however, exceedingly soft. Artesian water varies greatly in total hardness and in chemical content. In recharge areas it may be as little as 100 parts per million, but increases in proportion to the distance away from the recharge. Hardness of the water is caused primarily by magnesium and calcium bicarbonate, dissolved from the dolomites and limestones of the aquifer. Rain water is soft and filled with natural acids and as it enters the limestone aquifer and travels through it, more and more of the rock is dissolved and upon discharge the water may contain several hundred parts per million dissolved solids.

Where heavily mineralized waters are present in areas along the eastern Atlantic Coast and the southern Peninsula of Florida, well supplies are developed in shallow aquifers under water table conditions. The southern Peninsula ground surface is composed of very permeable limestones of Pleistocene and Miocene ages and the water supply is believed to be adequate for the large cities of the area. However, the eastern Atlantic area must depend on very shallow aquifers of limited distribution and an expansion of the present water supply must be sought in adjacent inland areas where surface or artesian waters can be utilized.

The use of large quantities of water in irrigation has developed a problem of increasing seriousness to the soils engineer. Waters containing low concentrations of solids in solution may drain to low surface areas, and mineral residuals from evaporation may concentrate and make the soils barran. Overhead irrigation may relieve this problem, if it is a local one, but the flushing out of these brines may gradually increase the percentage of salts lower in the drainage basin, to the detriment of other users.

Consumption of Water Resources: The average daily use of water in Florida is estimated to exceed two billion gallons per day. Of this amount about 59 per cent is ground water and 41 per cent is surface water. The large part (74%) of surface water is used in irrigation with about six per cent of the total being used for municipal supply and 20 per cent in industries.

More than one and one-fourth billion gallons per day of ground water is used, with about 32 per cent used for industry, 25 per cent for public water supplies, 35 per cent for agriculture and 8 per cent for domestic supplies.

To the doom peddlers, the heavy draft of two billion gallons of water per day from our water resources would seem to be excessive. These people do not consider the heavy rainfall nor the very large capacities of the State's elaborate and extensive artesian aquifer. There should be no alarm over these necessary uses, especially when the natural drainages from the aquifer in the form of fresh water springs of which Florida has a great number, exceeds three and one-half billion gallons of water per day and the total surface runoff for Florida is estimated at 40 billion gallons per day. This is about twenty times the total of water for all uses in the State, about the only use of the excess being in recreation.

For most of the State which obtains its water from the ground, there are four conservation problems. First, many wells are allowed to flow freely or the casing is so rotted as to be ineffective, and the water is put to no beneficial use. Senate Bill No. 57 (Florida Statutes 370.052 and 370.54) will help in combating this problem in that it required that all flowing wells be equipped with a valve, and fortunately the 1955 Legislature appropriated the necessary funds for enforcing and administering the law. The enactment and enforcement of this law will prevent the waste of water from flowing wells and will help to avoid salt-water pollution and lowered water levels in some areas. Secondly, large withdrawals of water from wells along the coastal areas have resulted in the invasion of well fields by salt water. Miami, Panama City, Tampa and St. Petersburg have all had to relocate their fields for this cause. Thirdly, some areas, particularly Orlando, formerly disposed of their sewage into the same limestone from which they took their water, resulting in pollution of the water supply and the development of large supplies of underground sewage gas. This practice is now forbidden by a State Sanitary Code, but sufficient sewage and citrus wastes have been drained into some of the limestone areas so that the decomposition is producing enough gas to allow its use in homes. Several homes in Orlando obtain their entire supply from their individual wells. Further, a developing use of water in air conditioning is taking a large draft of water. This water should be circulated out of the ground through the air conditioner and back into the ground or tremendous withdrawals will result.

As students and practicing soils engineers, agronomists and scientists, you can assist in water conservation by conditioning the soil, terracing, contour planting and cultivation and thus increase recharge to ground water; by protecting the soil from rain impact and wash in creating a vegetative cover and by mulching. But the best aid would be through the encouragement of the use of Federal facilities and soils engineering staffs provided under Public Laws 522, 566, 597, and 591, in the development of water control structures in the upper watersheds.

Variations in Florida's Surface Water Supplies*

W. E. Kenner **

INTRODUCTION

This paper discusses the nature and causes of variations in the surface-water supplies here in Florida. There is much in this paper that is not new, but in view of the tremendously increasing demand for new sources of supply for agricultural, industrial, and municipal use, the information bears repeating.

The word "source" is used to denote the stream, lake, or other surface water body from which water is withdrawn, and the term "surface water supplies" used to denote amounts of fresh water that are potentially available to be used consumptively. By this restrictive definition we remove the necessity of discussing the total contents of a water body and confine ourselves to the useable contents that may be skimmed off the top, so to speak. Further, we remove from discussion the saline surface waters along the coast.

Variations in the supplies are accurately reflected by variations of the source. Keeping this in mind, we proceed to a consideration of the sources, primarily streams and lakes, and their variations. We will consider first the streams, then the lakes.

STREAMS

The variations in flow of our streams can be divided into two kinds. We have the kind in which the average discharge per square mile of drainage area varies considerably from stream to stream throughout the State. We also have the kind in which, although the average discharge per square mile may be the same on each of two streams, the flows of the two do not increase nor decrease simultaneously or even similarly; the time-distributions of the flows are different.

To determine the cause of the variation in the first case—unequal yield—we need to examine the possible variations both in the amount coming into the basin and in the amount lost within the basin. The accretions to water in the basin come from precipitation, nearly all of which, in Florida, takes the form of rainfall, and from underground flow into the basin; the losses are from evaporation, transpiration, underground flow out of the basin, and consumptive use within the basin.

Unequal distribution of rainfall is oftimes the largest factor in producing unequal flows. In Florida we experience wide differences in long-term rainfall averages at points relatively close together. Annual rainfall totals are even more divergent. Rainfall in the lower East Coast section and in the Pensacola area averages nearly 50 percent more than the rainfall in parts of Levy and Dixie Counties.

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The amount of water that may enter a basin via underground formations varies widely throughout the State. Often this water issues as springs and we can gain some idea of its magnitude; probably as frequently, it comes in undetected and enters the stream through the streambed. The variation in streamflow that results from this factor can be extreme.

The losses that take place from basin to basin are subject to great variation. In Florida, evaporation losses may show large variations. In 1955, for example, the annual pan evaporation was almost 80 inches at Hurricane Gate 6 at Lake Okeechobee and less than 53 inches at Loxahatchee. Transpiration, varying with temperature, kind and amount of vegetal cover, and other factors, introduces another variable in the loss equation.

Just as water may come unseen into a basin by underground flow, it may also leave certain basins. Such flow must be listed as a loss when the latter occurs. There is an area of more than 100 square miles in north-central Florida from which no surface streams whatever flow. Apparently, underground formations allow all excess water to move out.

Although much of the water withdrawn for irrigation, or for domestic and industrial uses, may be returned or otherwise find its way to the stream, losses can occur in the interim. The magnitude of such loss is highly variable. When the water withdrawn is used for condenser cooling, for example, and is returned directly to the stream, only slight losses occur. On the other hand, when the water is used for irrigation as much as 75 percent of the water applied may be lost through evaporation and transpiration.

Thus we see that the average flow from a river basin in Florida depends upon a number of factors, each of which contributes a loss or a gain.

The other kind of variation—where time-distributions of flow are dissimilar—is a universal characteristic of streams but it seems particularly pronounced in Florida. Preliminary correlative studies have indicated that there is considerably more dissimilarity in Florida streams than in streams in many other areas.

Let us examine the factors that bring about the day-to-day fluctuations in the flow of a stream so that we may gain a better understanding both of fluctuations in streams and the lack of uniformity among streams. Much of the day-to-day variation is accounted for by the intermittent character of the primary runoff-producing factor—rainfall. Also, the sporadic nature of Florida's rainfall, particularly during the summer months when thunderstorms are prevalent, produces much of the variation in streamflow. Quite often daily observations at rain gages no more than a few miles apart have shown differences of several inches. A near-normal monthly total has been noted at one gage while another gage in the vicinity showed more than twice normal rainfall.

However, there are other factors related to the physical features of the land that to a greater or lesser extent retard the movement of water and thereby cause variations in flow at some downstream point. Size and shape of the drainage area are factors. If the distances traveled by the water are such that much of the runoff reaches a point on the stream simultaneously there will be a period of high flow followed by a period of relatively low flow. If, on the other hand, distances are such

that water from different parts of the basin reach the site at different times, peak flow will be lower and succeeding flow higher than if the flow converged simultaneously. Naturally, if long distances must be traversed by the water, the peak flow may occur several days or a week after the rain, whereas in small drainage basins the time may be short, a matter of several hours or even less.

The slope of the land surface determines to a large extent the rapidity with which the water reaches the main-stem streams. Steep slopes concentrate the water quickly, and relatively high peak flow, usually of short duration, is produced. More gentle slopes tend to result in lower peak flows of longer duration.

The existence of lakes, ponds, sloughs, and other natural depressions within the drainage basin tends to reduce the magnitude of peak flows by storing, at least temporarily, large quantities of water. Lakes that are part of river channels and wide flood plains have much the same effect.

The characteristics of the soil mantle in the drainage basin may influence greatly the amount of variation in stream flow. Soils that allow little infiltration tend to cause most of the rainfall to enter the streams at once with resultant high discharges, while the more porous soils may absorb large quantities of water and pass a part of it down to the water table, later to be discharged slowly to the streams. Water at times may pass directly from the stream channel into voids in the adjacent and underlying rock, where it is stored until a lowering of the river stage allows it to flow back into the channel.

The natural streams in Florida showing the least variation are those whose flow is derived principally from springs. Some, of course, show greater fluctuation than others, but these streams as a group are classed among the more dependable sources of supply.

LAKES

The lakes of Florida are vitally important as potential sources of surface-water supplies. The number of lakes is a matter of conjecture since no accurate count has been made; however, conservative estimates run as high as 10,000. Lakes are found throughout Florida but the majority are in the peninsular section of the State.

For convenience in discussing the nature and causes of variation in their levels with the passage of time, the lakes have been divided into three groups: (1) those that form part of a river channel; (2) those that are not part of a channel but have an outlet to some stream; and (3) those that have no outlet and are commonly referred to as land-locked lakes.

The lakes of the first group—those similar to Lake Monroe, for example—merely function as part of the stream channel, and as such their levels vary with the level of the stream. Excessive withdrawals from such a lake is usually accompanied not only by a lowering of the level of the lake but also a lowering of the stream level for some distance upstream and downstream.

The lakes of the second group—those not on a channel but having outlets—tend to vary somewhat less than lakes of the first group. Exceptions are noted, as in the case of Orange Lake, which fell several feet below any previously recorded minimum as a result of the recent dry

period in that area. Excessive rises in the level of lakes in this group may occur in wet weather if outlet channels have insufficient capacity.

Lakes in the third group—those with no outlet—may be further divided into "perched" lakes and "water-table" lakes. The term "perched" is applied if some impervious layer beneath the lake effectively seals it off from the ground water body. It becomes, in effect, a bowl of water and variations in its level follow as a result of above-ground additions or subtractions. Generally only slight underground movement of water to or from the lake occurs. Rainfall in excess of evaporation and transpiration requirements results in a rise and, conversely, a deficiency of rainfall results in a lowering of the level. A long continued rainfall deficiency or excessive withdrawals may result in the lake becoming dry.

A "water-table" lake, of which Florida has many, has an opening or openings between the lake bed and the water-table aquifer through which water may pass. The lake surface assumes the same elevation as the surrounding water table and fluctuates as the water table rises and falls. A sudden addition of water to the lake, as from a heavy rain, may cause the lake level to rise somewhat, but unless the materials forming the lake bed are tightly packed the level soon falls to that of the water table as the excess water passes downward and is added to the water-table body. Similarly, withdrawals from the lake are replaced by water moving into it from the surrounding water-table body. Therefore, such lakes are usually dependable sources of supply.

CONCLUSIONS

In conclusion, the numerous lakes and streams of Florida constitute a vast and potentially very valuable source of surface supplies. Variations in stream flow and lake levels take place constantly and their effect is to place practical limits on the utilization of each source. The variations are the result of the interaction of various climatic, topographic, geographic, geologic, and hydrologic factors. A better understanding of these factors and of their effects can make easier and more complete the utilization of one of Florida's most important natural resources.

Quality of Florida's Surface and Ground Water Resources

A. P. Black *

CONSTITUENTS OF NATURAL WATERS

Water falling upon the earth in the form of rain or snow contains practically no dissolved mineral material. its content being usually limited to the gases of the atmosphere—especially oxygen and carbon dioxide. As this water percolates into the earth and becomes part of the ground water it begins to exert a solvent action upon the rocks through which it passes. This solvent action is greatly increased by the presence of the carbon dioxide, absorbed from the atmosphere and from the soil, where it is formed by organic processes. The amount and the character of the dissolved mineral matter depends upon the chemical and physical composition of the rocks through which the water passes, the temperature, pressure. and duration of contact, as well as the presence of other dissolved material.

A chemical analysis, as usually reported, includes results for total dissolved solids. silica, iron. calcium, magnesium, sodium and potassium, bicarbonate, sulfate, chloride, nitrate, pH, and total hardness. The constituents are reported in parts per million, the abbreviation for which is ppm. One part per million is equivalent to one milligram of a given constituent in one liter of water or, expressed in English units, equivalent to 8.34 pounds of constituents per million gallons of water.

Total Dissolved Solids

The values reported under total dissolved solids indicate approximately the total amount of dissolved mineral matter in the water. This is obtained by evaporating a known quantity of the water to dryness and weighing the residue after it has been dried at a definite temperature. This figure will include any organic material present, as well as some water of crystallization. The latter varies with the type of water and the temperature at which the residue is dried. In many cases there is little agreement when the value for total dissolved solids is compared with the sum of the mineral constituents. This may be due, in part, to water of crystallization, organic matter, loss of chloride during drying, and failure to report fluorides and nitrates. In the case of high bicarbonate waters, the reported figure for total dissolved solids will always be considerably less than the sum of the constituents because of the fact that during the process of evaporation the bicarbonate ion is broken down with the loss of water and carbon dioxide. The apprent discrepancy will be directly proportional to the total alkalinity of the water. This decomposition takes place according to the following reaction:

$$Ca(HCO_3)_2 \longrightarrow CaCO_3 + CO_2 + H_2O$$

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Waters with less than 500 ppm of dissolved solids are satisfactory for domestic and most industrial uses. The quality of irrigation waters is determined not only by the amount of dissolved solids present, but also by the amounts of certain ions which have been found to exert specific effects. These will be discussed later.

The total dissolved solids encountered in Florida waters ranges from only a few ppm in the surface waters to many thousand ppm in the deeper ground waters. The highly mineralized waters, however, are rarely used except for fire protection and in some instances for irrigation.

Silica—(SiO_2)

Since silica comprises more than 60% of the earth's crust, it is not surprising to find it in practically all water. Although its state in natural waters is not definitely known, it is generally assumed to exist in the colloidal state, not affecting the equilibrium between the acids and bases. It is therefore usually reported as SiO_2 and not in the ionic form. Since the silica content of Florida waters generally varies from about 5 to 30 ppm, it is of relatively little importance except where this amount may contribute to scale formation in boilers used for the production of steam.

Iron—(Fe)

Iron is dissolved from many rocks, but not, however, in the quantities normally found for other constituents. It is usually present in the form of ferrous bicarbonate. Iron present as bicarbonate may be removed by aeration which results in decomposition of the bicarbonate and oxidation of the iron to the ferric condition. The reaction is as follows:

$$4Fe(HCO_3)_2 + O_2 + 2H_2O \longrightarrow 4Fe(OH)_3 + 8CO_2$$

However, in those instances where iron is combined with organic matter, it may not be so readily removed and additional treatment is necessary. Although iron is rarely found in surface waters in Florida, and is found only in traces in water from deep-seated artesian wells, it is a fairly common constituent of water derived from shallow wells in many areas of the state.

Calcium and Magnesium—(Ca-Mg)

Since the limestone aquifers underlying the entire state consist essentially of calcium carbonate with varying amounts of magnesium carbonate, it is not surprising that many ground waters derived from them contain considerable amounts of both. Their solution is brought about by carbon dioxide, according to the following reactions:

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$$
$$MgCO_3 + H_2O + CO_2 \longrightarrow Mg(HCO_3)_2$$

Other, although less-widespread, sources of calcium are gypsum, or calcium sulfate, and dolomite. As the latter is a double carbonate of calcium and magnesium, it serves as an important source of dissolved magnesium in Florida waters. Several areas of the State owe their rather high content of both calcium and magnesium to solution of marine deposits or to present-day intrusion of sea water along the coastline.

In connection with the source of calcium and magnesium in Florida waters, it is interesting to note the relative concentrations of these elements in water from various geologic horizons. Waters from the Eocene formations in areas unaffected by salt water intrusion or solution of marine residuals are apt to contain about half as much magnesium as calcium; the sulfate content may also be high, often equaling the bicarbonate concentration, while that of both sodium and chloride is low. Water from limestone formations of Pliocene and Pleistocene ages in many parts of the state, however, often contains very little magnesium, the concentration of this element being as little as 1/10 to 1/20 that of calcium.

Strontium—(Sr)

Until recently few analyses for the presence of strontium in Florida waters have been made. However, recent work has focused attention on the presence of this element and it has been found to occur along with the calcium and magnesium in many natural waters.

Sodium and Potassium—(Na-K)

Sodium and potassium are found in all natural waters, but usually in comparatively small quantities in most potable supplies. In waters containing only a few ppm of sodium and potassium, it is found that the amount of potassium is somewhat less than that of sodium. As the total quantity of these elements increases, it is further found that, as a rule, the concentration of sodium greatly exceeds that of potassium.

Moderate amounts of sodium and potassium have no effect on the suitability of water for all domestic and most industrial purposes, or for irrigation. Significant amounts of sodium are found only in highly mineralized ground waters as a result of salt water intrusion, or solution of marine residuals. Since irrigation with flowing artesian wells is extensively practiced in certain areas of the state, the amount of sodium is of considerable interest, as the permeability of soils to irrigation water may be affected by the sodium content of the water used. Certain "heavy" soils such as clays, appear to swell when saturated with sodium ions and thus become impervious. In the sandy type soil found throughout much of Florida, the chief effect of saline irrigation water is the increase in concentration of salts, producing a condition toxic to plant growth. The effect here thus appears to be chemical in nature, rather than a change in the physical structure of the soil. As with other constituents in Florida waters, the quantity of sodium is quite variable, ranging from 5 to 20 ppm in most well waters to several thousand ppm in the highly mineralized waters resulting from salt water intrusion or solution of marine deposits.

Bicarbonate—(HCO_3)

The total alkalinity of a water is the sum of its hydroxide (OH), carbonate (CO_3), and bicarbonate (HCO_3) alkalinities, all expressed in terms of equivalent quantities of $CaCO_3$. Of the three, the bicarbonate is the one most commonly found in Florida waters. Bicarbonate in natural

waters results from the solvent action of water containing carbon dioxide on carbonate rocks, the equation for which has been given previously.

Ground waters in Florida usually contain from 100 to 300 ppm of bicarbonate ion. Surface waters have much less.

SULFATE—(SO_4)

Sulfates and chlorides are normal constituents of practically all water supplies, although the concentrations may vary very widely. As a rule, surface waters are relatively low in sulfates and the same is true of shallow wells in many parts of the state. The presence of large concentrations of both sulfates and chlorides in ground waters is due to the solution of marine deposits in the aquifers from which the waters are derived. As a rule, waters high in sulfates are likely to be high in chlorides, although there are some striking exceptions. A well in Lake City, Florida, drilled to a depth of 1,125 feet, contained 1,068 ppm of sulfate, and only 25 ppm of chloride. Waters derived from the Miocene Hawthorne formation in Southwest Florida contain a higher content of sulfate than of chloride, and the same is true of certain waters in Flagler and Volusia counties.

CHLORIDE—(CL)

Chlorides are dissolved from practically all rocks and soils. Ocean spray is carried by the wind far inland, where salt is deposited with the rain. A high chloride content in surface and ground water near the ocean may be due to this agency alone, while the more remote areas for inland are less affected. In addition, many areas show extremely high chloride values due to intrusion of sea water into ground waters along the coastline, and through solution of salt deposits laid down by ancient seas. Domestic and industrial wastes may contribute greatly to the chloride content of some ground and surface waters.

The chloride content of Florida waters is highly variable. As in the case of sulfate, it is not possible to give any value for the normal, or average, chloride content of Florida waters. Chloride may vary from as little as 5 ppm to as high as 1,000 ppm, the latter figure, however, being only in very exceptional cases, since this figure exceeds the maximum content permissible for potable waters. Some wells drilled in search of oil have encountered water containing more than 50,000 ppm of chloride.

NITRATE—(NO_3)

No waters high in nitrate have as yet been reported in Florida.

HYDROGEN-ION CONCENTRATION—(pH)

The hydrogen-ion concentration of a water is a measure of its momentary acidity. Pure water contains 10^{-7} grams of hydrogen-ion per liter. In order to avoid the use of exponential numbers, a simple system involving the use of so-called pH values has been developed. In this system pure water has the pH value of 7.00. Waters having pH values of less than 7.00 are acid, the acidity increasing as the pH value decreases. Conversely, waters having pH values greater than 7.00 are alkaline, the alkalinity increasing as the pH value increases.

The pH value of most natural waters depends upon the amount of free carbon dioxide, and the amount and character of the types of alkalinity present. Since free carbon dioxide is readily lost from water samples upon standing, the determination of the pH values should be made in the field at the time the sample is collected, if an accurate value is desired. Values determined from samples which have been bottled and shipped will not always represent the true pH value of the water. Samples high in alkalinity will usually undergo only small changes in pH value on standing, due to the high buffer capacity. However, in the case of soft waters high in free carbon dioxide, the pH value of a sample which has stood for some time will usually be substantially higher than that of a sample measured in the field.

Most deep ground waters are slightly alkaline and their pH values usually vary within the range pH 7.0-8.0. Soft surface waters on the other hand may be acidic due both to the presence of free carbon dioxide and acidic constituents derived from organic material. The pH of such waters will usually vary between pH 6.0-7.0. It is worth noting that the presence of algae and diatoms in Florida's many lakes may give rise both to unusual pH values, and to very rapid daily and hourly changes in these values. These organisms contain chlorophyll and carry on their life processes by the action of photosynthesis. This results in the removal of free carbon dioxide from the waters, following which these organisms can remove carbon dioxide from bicarbonates, converting them to normal carbonates. Since photosynthesis is carried out only during the day, requiring sunlight, this means that the waters in such lakes will be most acid early in the morning, and most alkaline in the later afternoon. Changes in pH from 6.5-8.5 during a single day have been observed.

TOTAL HARDNESS—($CaCO_3$)

As previously indicated, the hardness of a water is due to the salts of calcium and magnesium carried in solution. Other constituents, such as iron, aluminum, zinc, barium, strontium and free acid may cause hardness, but none of these are present in Florida waters in amounts sufficient to have any effect upon the total hardness.

There are two types of hardness in water, now designated as carbonate hardness and non-carbonate hardness. These terms have replaced the terms "temporary" and "permanent" found in the older literature. Carbonate hardness is that portion of the total hardness due to the presence of the carbonates and bicarbonates of calcium and magnesium; non-carbonate hardness to the presence of sulfates, chlorides, and nitrates of these elements.

COLOR

Color in water may be due to the presence of iron or to the presence of organic material dissolved from leaves, roots, soil, or other organic matter with which the water comes in contact. If the color is due to iron, the water as drawn from the well is usually clear and colorless, and the color develops on standing. Organic color, on the other hand, is present in the sample as collected and is usually accompanied by a leafy, grassy, or moldy odor which gives a clue to its origin. Although color is usually present in many surface waters, it is very frequently present in Florida

in water derived from wells. This results from the fact that the limestone formations which underlie practically all of the state are porous and permeable and are frequently connected on the surface by sink holes permitting colored water to find its way into the underground formation and from there into wells penetrating these formations. Further evidence of this is afforded by the fact that many well waters in Florida have little or no organic color during the dry winter months, but become highly colored during the summer months of high rainfall.

Fluoride—(F)

Although compounds of Fluorine are widely distributed in the rocks of the earth, it is only in recent years that attention has been focused upon their presence in public water supplies. It may be stated, in general, that surface waters of all types are apt to be free from the element or to contain it in traces only. On the other hand, wells deriving their water from the Hawthorne formation of Miocene age almost invariably contain the element and usually in concentration in excess of 1.0 ppm, and which may reach 2.5 ppm. The largest area in which untreated deep well waters contain relatively high concentrations of fluorides is the tier of 9 counties (Manatee, Hardee, Sarasota, DeSoto, Charlotte, Glades, Lee, Hendry, and Collier) in Southwestern Florida. In other smaller areas of the state, such as the section surrounding Jacksonville in Northeast Florida, waters from deep wells contain significant amounts of the element.

Hydrogen Sulfide—(H_2S)

Hydrogen sulfide is found in a large majority of deep well waters in Florida, particularly water from flowing artesian wells, resulting in the very pronounced taste and odor which has given these waters their common name of "sulfur water". There are two possible sources of this gas in natural waters. One is the reduction of sulfates to sulfides by organic material under the anaerobic conditions obtaining in deep wells, with the resultant decomposition of the metallic sulfide by free carbon dioxide, to produce the gas, hydrogen sulfide. In some cases, it may be derived from the anaerobic reduction of organic matter with which the waters come in contact. The concentration of hydrogen sulfide in deep well waters in Florida is highly variable, ranging from traces to more than 4 ppm. Upon aeration, part of the gas is eliminated and the remainder is rapidly oxidized by dissolved oxygen absorbed upon aeration. This means that special sampling and analytical methods must be used if the gas is to be determined in water. For this reason relatively few values for hydrogen sulfide are reported.

Turbidity and Suspended Matter

The turbidity of water is due to suspended matter, such as clay, silt, finely divided organic matter, microscopic organisms, and similar material. A distinction should be made between the terms "Turbidity" and "Suspended Matter". "Suspended Matter" is that portion of the residue on evaporation not in solution in the sample. "Turbidity" is an expression of an optical approximation of the suspended matter, based on the

similiarity of interference to the passage of light rays through a water sample when compared with standard samples of recorded turbidity.

The standard unit of turbidity is considered as that produced by one ppm of silica (diatomaceous earth or fullers' earth) in distilled water.

Most well water, spring waters, and waters from rivers and lakes in peninsular Florida contain little or no suspended matter. The only rivers in the state carrying water of high turbidity are those crossing the Northwestern portion of peninsular Florida, and whose drainage basins lie mainly in the states of Alabama and Georgia. It is to be noted that clear deep-seated artesian waters often develop a faint marked turbidity upon standing. This is due to the oxidation of hydrogen sulfide to free sulfur. In a similar manner clear and colorless water from shallow wells high in iron will quickly develop both a high turbidity and a sediment of ferric hydroxide on standing.

Quality of Surface Water

The chemical character and physical properties of Florida surface waters vary so widly that only a general description can be given.

The majority of Florida's thousands of lakes occupy partially-filled depressions formed by solution of the underlying limestone. They are generally fed by local recharge and are therefore low in dissolved solids.

As a rule, those lakes receiving the discharge from rivers or springs draining swampy areas contain water high in organic color; lakes which do not receive such surface drainage usually have water which is low in color. The water of Lake Okeechobee, Florida's largest lake, is low in dissolved solids and high in organic color along its northern shore, but much higher in dissolved solids and lower in organic color along the southern shore. As the water moves across the lake, the solids become concentrated by evaporation, and much of the color is removed by oxidation and the bleaching action of sunlight. In the summer months of high rainfall, water along the southern shore of the lake may become both highly colored and highly mineralized by the reversal of flow of the water in the canals which enter the lake.

The rivers of Florida that are fed by shallow ground water percolation and surface run-off are low in dissolved solids and the water may contain considerable color. Those which receive a portion of their flow from the larger springs contain much more dissolved material, ranging up to 200 to 300 ppm, and are typically low in color. Due to the low gradient of the Coastal Lowlands, rivers flowing into the sea are brackish and high in dissolved solids for a considerable distance inland, unless protective works are present.

Springs in Florida deriving their flow from the ground water above the limestone aquifer are relatively soft and usually contain less than 50 ppm of dissolved solids. Water from those large springs originating in the limestone formations is harder and contains much more dissolved material. The chemical character of the water from these springs is similar to that from wells in the area drawing from the same aquifer, and varies somewhat with the location of the spring. For example, Wakulla Springs in Wakulla County carries dissolved materials to the extent of only 167 ppm, while Hampton Springs in Taylor County is mineralized to the extent of 914 ppm of dissolved solids.

Quality of Ground Water

It has been stated that the entire state is underlain by sedimentary limestone formations of varying age, from which large quantities of water may be obtained.

If observations are made of the height to which water will rise in cased wells penetrating these limestones and lines are drawn on a map through the points where these values are the same, there is obtained a piezometric map showing with considerable accuracy the elevation of the water surface throughout the formation. Such a map is of greatest importance in a study of ground water in Florida. For example, within a small area in Polk County between Lakeland and Haines City water will rise in cased wells penetrating these formations to a height of 120 feet above sea level. This is called the "Southern Piezometric High". The water levels slope downward from this area fairly regularly in all directions. It then represents a typical area of recharge within which surface water finds its way into the formations and flows down them along their slope. Another large high, the so-called "Northern Piezometric High", extends in a broad band from just north of Palatka in Putnam County through Bradford and Baker counties, and into Georgia. Smaller sub-highs are located in Pasco County, near DeLand in Volusia County, near Dunnellon in Marion County, and just south of Madison in Madison County. Since water, whether on or below the surface, "always flows downhill", a well-charted piezometric map affords invaluable information with respect to the direction of underground water flow. It shows, for example, that surface water recharged into the Southern High in Polk County may be recovered under considerable artesian pressure along the lower east coast of Florida as far south as Miami, and also along the west coast from Tampa southward to Fort Myers. It likewise shows that water recharged into the Northern High in Bradford and Baker counties may be recovered under even higher artesian pressures from the municipal wells supplying Jacksonville. Areas of artesian pressure are, of course, those areas where the elevation of the ground surface with respect to sea level is less than the head of water in the formation penetrated.

It is evident that the degree of mineralization of water drawn from this artesian aquifer in any given area of the state will depend to a large extent upon the distance traveled by the water since its entry into the formation in the area of recharge.

Since these formations are composed largely of calcium carbonate, with some magnesium carbonate, it is to be expected that the waters obtained from them might be properly classified as calcium bicarbonate waters. Certain local conditions, such as salt water intrusion or solution of marine residuals, may result in a change in the dominant radicals such that waters obtained in some coastal areas are more correctly described as sodium chloride waters. Local variations in the chemical composition of the aquifer may permit solution of sufficient quantities of sulfate, or other ions, to further alter the classification of the water.

Due to the large areal extent of the limestone aquifer, it is possible to consider the entire state as a single hydrologic unit. However, to facilitate discussion of the ground water in greater detail, it is convenient

to divide the state into three sections: Western Florida, Northern Florida, Central, and Southern Florida.

1. Western Florida. For the purpose of this paper, Western Florida comprises the counties west of the Aucilla River—Jefferson, Leon, Wakulla, Gadsden, Liberty, Franklin, Jackson, Calhoun, Gulf, Holmes, Washington, Bay, Walton, Okaloosa, Santa Rosa, and Escambia. This division is purely arbitrary and does not follow exactly either topographic or stratigraphic boundaries.

In contrast to peninsular Florida, whose bedrocks consist of chemically precipitated limestone, the bedrocks of Western Florida are composed of clastic material mechanically deposited by wind and water in the form of clay, sand, and gravel. Although limestone beds of late Eocene, Oligocene, and Miocene age are found near the surface only in Holmes, Washington, and Jackson counties, late Oligocene and Miocene beds may serve as sources of water in nearly all counties of Western Florida except Escambia, Santa Rosa, Franklin, and Gulf. The Citronelle, a non-calcareous formation of Pliocene age, furnishes water to Escambia and Santa Rosa counties with an average hardness of about 30 ppm. The sandy Pleistocene terrace deposits underlying Franklin and Gulf counties are quite susceptible to salt water intrusion, as is evident from the high hardness, chloride and sulfate content of the Apalachicola supply. Soft water with a hardness of some 35 ppm found in the southern portion of Okaloosa and Walton counties is evidently derived from the non-calcareous Pliocene and Pleistocene deposits. Analysis of water from wells of the same depth in the northern half of these counties indicates an origin in the limestone formations of Oligocene and Miocene age supplying Washington, Holmes, Calhoun, Jackson, Liberty, Gadsden, Wakulla, Leon, and Jefferson counties. Water in these counties has a total hardness ranging from 130 to 200 ppm, and is typical of moderately hard limestone water obtained throughout the state.

2. Northern Florida. For this paper Northern Florida comprises those counties east of the Aucilla River and north of the 29th Parallel. Along this line may be found the "trough" that roughly separates the two great "piezometric highs" previously described. Although the chief aquifer of this region is the Ocala limestone, of late Eocene, the Avon Park limestone of middle Eocene age is locally important in Citrus, Levy, and Volusia counties where the Ocala has been eroded away. Where large supplies of water are required as for the municipal supplies for the City of Jacksonville and the pulp industry at Fernandina, wells have been drilled through the Ocala into the Lake City limestone, of middle Eocene age. The Lake City Well No. 5 was drilled down to the Oldsmar limestone, of early Eocene age, where highly mineralized water was obtained. This water contained 1,068 ppm of sulfate, with a total hardness of 1,297. The chloride content, however, was only 25 ppm. The oil test well drilled at Hilliard in Nassau County obtained water from the Cedar Keys limestone (of Paleocene age) at a depth of 2,225 feet. This water contained 3,912 ppm of sulfate, 33,600 ppm of chloride with a total hardness of 9,655 ppm. Water from the same well at a depth of 4,500 feet from the Tuscaloosa formation (early Gulf Series) contained 60,200 ppm of chloride with a hardness of 14,961 ppm. The Sholtz Oil Test Well No. 1 at Cedar Keys in Levy County obtained water at a

depth of 2,822 feet from the Lawson limestone (late Gulf Series). This water contained 69,500 ppm of chloride with a total hardness of 18,494 ppm. It is evident that the older formations underlying the middle Eocene beds in Northern Florida contain connate brines, which indicates that a certain amount of caution must be used in drilling wells to the deeper formations in search of large supplies of water for municipal or industrial use or for irrigation.

The Suwannee limestone of the late Oligocene age is an important source of ground water in Citrus, Hamilton, Lafayette, Madison, Suwannee, and Taylor counties in the eastern portion of Northern Florida. Since the composition of this limestone is about the same as the Ocala, water of a similar mineral content is found in this area. Other formations of Miocene to recent age are used locally as sources of ground water. Since less water is available in these younger formations, their use is usually confined to domestic and smaller municipal supplies. The water obtained is generally softer than that obtained from the deeper formations, although more variable in composition. On the other hand, wells drilled into the Anastasia formation (late Pleistocene) at St. Augustine produce water whose hardness of 500 ppm exceeds that from the Eocene limestones.

3. Central and Southern Florida. This section of Florida is taken to include those counties of the peninsula lying south of the 29th Parallel. A study of the piezometric surface of this region indicated a recharge area centering between Lakeland and Haines City in Polk County. Wells penetrating the Eocene and Oligocene limestone in Polk and surrounding counties obtain water whose hardness averages from 50 to 200 ppm. Being far inland, the chlorides range from 5 to 20 ppm, and sulfates rarely exceed 20 ppm. As the distance from the recharge area increases, the mineral solids increase. This increase in mineralization is modified in some areas by changes in chemical composition of the aquifer, the presence of connate or residual sea water within the formations or salt water intrusion. Only moderate increase in mineralization is noted in the area north of the recharge area, principally because the aquifer is at or near the surface, and surface recharge is more evident. Also much of this area was not covered by the Pamlico Sea, and has therefore had sufficient time to become flushed of previous saline deposits. As mentioned previously, this is not the case along the valley of the St. Johns River, where highly mineralized water is found at moderate depths. In the coastal area of Volusia County, the artesian aquifer lies at or near the surface, in contact with sea water. Excessive withdrawals of ground water in this area may permit the entry of saline water into the porous limestone formations. This same situation may be found in other coastal areas, where ground water levels have been reduced to a point where the pressure of fresh ground water is no longer great enough to hold back sea water.

Along the coastal fringe from Volusia to Dade County water from the artesian aquifer is too highly mineralized to be used as a source of municipal supplies, often having a total hardness ranging from 500 to 1,000 ppm, with chlorides and sulfates of the same magnitude. Where the Pliocene and Pleistocene deposits furnish insufficient water or water

that is also too highly mineralized due to marine residuals, surface supplies must be relied upon.

Along the west coast of Central Florida, as far south as Hillsborough County, water produced by the Eocene and Miocene formations is relatively less mineralized, this area being located fairly near the southern recharge area. An obvious example of the effect of salt water intrusion resulting from excessive draw-down may be found in the abnormally high chloride content of the New Port Richey and Tarpon Springs supplies in Pasco County. The coastal counties south of Hillsborough are still able to secure artesian water, chiefly from the Hawthorne formation and Tampa limestone formation of Miocene age. Water from these formations, however, is generally too highly mineralized for domestic use, being chiefly utilized for irrigation purposes. A striking feature of these waters is the excess of sulfate and chloride over bicarbonate. The high calcium and sulfate content suggests contact with gypsum, as well as marine residuals. Sarasota County is also one of the few areas in the State where water from the Eocene and Miocene deposits is high in fluoride. This element occurs here to the extent of 1 to 3 ppm, in water with a hardness of some 1,000 ppm, chlorides of 200 ppm, and sulfates of from 400 to 800 ppm.

In the several thousand square miles of the Florida Everglades, not only is the water from deep artesian aquifers so highly mineralized as to be of little use, but the same is true of water from shallow wells drilled in most parts of the Everglades. This results from the fact that the Everglades, including Lake Okeechobee, was covered by several inundations of the sea, thoroughly saturating the limestone formations with highly saline water. The exceedingly low gradient existing in this area, together with the low permeability of the formations and a high rate of evaporation of surface water, has permitted little of this saline material to be flushed from the aquifer by percolating ground water.

In Palm Beach County the Tamiami limestone, and in Dade County the Tamiami limestone and the Miami oolite constitute very prolific aquifers for shallow wells. The wells supplying the Hialeah Water Treatment Plant of the City of Miami, drilled to depths varying from 62 to 120 feet, yield an average of three to four million gallons per day per well with very little draw-down. The new wells supplying the Southwest Water Treatment Plant of the City of Miami, varying in depth from 98 to 101 feet, on pumping tests yielded as high as 10 million gallons per day.

SOURCES OF INFORMATION CONCERNING WATER QUALITY

The year 1951 witnessed the publication of two fairly comprehensive sources of information with respect to the chemical quality of Florida's surface and ground waters. The first was Water Survey and Research Paper Number 6, "Chemical Character of Florida's Waters". This publication presents the chemical analyses of 1,921 samples of water, of which 116 were water from springs, 90 were water from lakes, and 49 were water from rivers. A few copies of this publication are still available and may be obtained from the Florida Geological Survey, Tallahassee, or the Division of Water Research of the Department of Chemitsry, University of Florida.

The second was University of Florida Agricultural Experiment Station Bulletin 480, "The Chemical Composition of Irrigation Water Used in Florida Citrus Groves". This publication presents the analyses of 256 samples of water from irrigation wells in Brevard, Indian River, St. Lucie, Pinellas, Charlotte, Lee, Manatee, Sarasota, and Polk Counties. When one adds Collier, Okeechobee, and Seminole to this list of counties, the list then includes practically every Florida county in which water from irrigation wells is likely to contain dissolved mineral salts in concentrations which might prove injurious to growing crops. Numerous analyses of water from these three last mentioned counties will be found in the first reference.

Of Florida's numerous springs, only Blue Spring in Volusia County, Hampton Springs in Taylor County, Homosassa Springs in Citrus County, Salt Springs and Silver Glen Springs in Marion County, Big and Little Salt Springs in Sarasota County, and the five mineral springs of Safety Harbor in Pinellas County contain total dissolved solids in excess of 1,000 ppm. Of all recorded analyses of Florida lake waters, only that from Lake Clear near Cocoa in Brevard County exceeds 1,000 ppm and that only at times. No Florida river contains water having total dissolved solids as high as 1,000 ppm.

SALT WATER INTRUSION

The problem of salt water intrusion along both the east and west coasts of the state has receievd increased attention during the last few years and the possibility of a significant increase in the salt content of water derived from wells along coastal areas must never be overlooked. However, it should be pointed out that the presence of high concentrations of total dissolved solids in wells in coastal areas does not necessarily mean that salt water intrusion is present. Along most of the east coast and much of the lower west coast of the state the high content of total dissolved solids in irrigation waters results from the leaching of saline residuals from the aquifer from which the water is derived. As this leaching continues with use such waters will have a tendency to decrease, not increase, in salt content. This decrease will be so slow that its effects are not likely to be noted within an observational period of time. It is usually possible to chemically differentiate such "residual brines" from waters contaminated with sea water because the ionic ratios are substantially different in the two types of waters.

EFFECT OF MINERAL SALTS IN IRRIGATION WATER ON SOILS AND PLANT GROWTH

It probably should be noted in passing that damage resulting from high total dissolved solids in irrigation water is of two general types. In the first type total dissolved solids originally present in the soil solution become concentrated by successive irrigations and loss of water by evaporation and evapo-transpiration to a point where the osmotic pressure of the soil solution is deterimental to plant growth.

The other serious effect of dissolved solids in irrigation water is the effect of high sodium on soil texture. It results from the fact that when waters high in sodium are used for irrigation, the sodium ion replaces

the calcium and magnesium ions of the soil complex by base exchange, resulting in a soil which is difficult to cultivate, hard and lumpy when dry, and sticky when wet. This behavior is characteristic of clay soils with high base exchange properties but is not nearly as pronounced in the sandy soils in Florida as it is in the clay soils of the central plains and the west.

However, according to Wander & Reitz (*loc cit*) because of relatively high rainfall and soils of low clay content, the use of irrigation water on citrus in Florida presents a problem different from that found in many other citrus growing areas. In fact, water containing larger amounts of salts can be used under the climatic and soil conditions of Florida than could be used if the climate were drier and the soil heavier. Young(1) grew citrus seedlings in waters of known salt content in the greenhouse and concluded that relatively high concentrations of sodium chloride alone were not detrimental to growth. Forsee(2), studying the effect of the salt content of water on potatoes growing in certain sandy soils in Lee County, came to somewhat the same conclusions. He found that the consistent use of irrigation water containing less than 750 ppm equivalent of sodium chloride showed no visible trace of salt injury to the growing crops. Injury was observed on fields where the water contained considerably in excess of 1,000 ppm.

Probably because of Florida's relatively high rainfall and soils of low clay content, relatively little work has been done in the state on the effect of dissolved salts in irrigation water. With the steady trend toward increased irrigation in all parts of the state, it would seem importnt that additional studies be undertaken in those areas where damage from highly saline waters might be expected to occur.

REFERENCES

1. Young, T. W., Florida Agricultural Experiment Station Annual Report, pp. 288-292 (1949).
2. Florida Agricultural Experiment Station Annual Report, pp. 173-174 (1946).

WATER UTILIZATION

Wednesday, November 28—1:30 P.M.

RUSH E. CHOATE, Moderator*

Florida's Industrial Water Requirements and Utilization

GEORGE D. HACK**

INTRODUCTION

At no time in history has man's attention been more intensely focused on water supply problems than at present. This condition exists in varying degrees throughout the entire world and is altered only by a balance between supply and demand. Availability of water governs, to a large degree, the expanding economy of practically all peoples. Since there is no universal qualitative or quantitative specification for water requirements in different areas throughout the world, there can be no common solution to such problems.

The history of man from antiquity has been entwined with water supply, and no nation has expanded or, in fact, long survived in the absence of sufficient water to support national groups and development.

An ample supply of water and means for disposal of wastes are primary requisites of almost all industries. Industrial development in any area is closely related to the fulfillment of these two requirements. It is interesting to note that according to figures released by the Journal of American Waterworks Association in 1953, which gives estimated values of water consumption in the United States for the year 1950, that industrial water consumption is exceeded only by irrigation requirements.

Never in the experience of this country has industrial growth and development reached such an accelerated tempo as is now occurring. Increased water demands can be attributed in no small measure to research and development which has taken place in recent times. Both during and since the war, great strides have been made in all fields, especially in electronics, organic synthesis, anti-biotics, aviation and other industries too numerous to mention here. It is a natural consequence, therefore, that our expanding economy continuously demands new industrial plants, in addition to plants required to meet the previous needs of basic industries.

There is increasing concern and perhaps hysteria at times regarding water shortages throughout the country. The latter is not justified, although it is a fact that due to over industrial development and wasteful practices, there are a number of critical water areas. The problem, however, is in many respects not so much a lack of water but a lack of long term intelligent planning.

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FLORIDA WATER-USING INDUSTRIES

The industrial water requirements in Florida are more diverse than any other water user in the State. Some industries' operations require no water while others use tremendous volumes of this natural resource.

There are four major categories of industrial water users in Florida. Their combined water requirement represents about 90 percent of the total industrial water requirements of the state. These four categories are:

1. Electrical power production
2. Pulp and paper manufacture and general chemical industry
3. Citrus processing
4. Mining.

In this presentation I have outlined briefly the first three categories using case studies to emphasize the variability of utilization.

Electric Power Production

At present, the production of electrical power in Florida is accomplished by hydro-electric and by steam generating power plants. Hydro-electric plants do not play a prominent part in the state picture since there are few sites which are satisfactory for impounding the water and developing the head necessary to operate the turbines.

The water requirement of a steam generating plant is such that the quality of water used does not play an important part in the operation. A number of plants use brackish or salt water for cooling purposes, but many plants must be located where only fresh water is available. An electric generating station uses about 80 gallons of water per kilowatt of electricity generated. The average electric generating station may use 500,000 gallons of water per miunte. In 1956 the fresh water requirement of the power manufacturing industry in Florida averaged over 1,590 million gallons daily. Of this amount, only 2% was obtained from ground sources. In general, the water is not impaired in quality since it is subjected only to a slight temperature rise and is diminished in quantity by only about 4%.

PULP AND PAPER MANUFACTURING AND CHEMICAL INDUSTRIES

The manufacture of pulp and its attendant end products of pulp wood and the manufacture of various chemical products are becoming an important part of the industrial picture in Florida. Most of these industrial sites have been selected after giving primary consideration to the area's water resources. Some processes such as the manufacture of ammonia and other nitrogen compounds use the water as a raw material from which the end product is made. Others require water for various processes, operation, and cooling purposes. No two industries require the same quantity or quality of water and even industrial plants of the same type of industry vary in their requirements. To point up this variability in water requirements, I have chosen a few case histories of specific industrial uses that I would like to cite as examples. First a sulphite pulp bleaching

mill's average demand is approximately 60,244 gallons of water to bleach 1 ton of dry pulp whereas, the manufacture of a ton of paper board requires 14,000 gallons.

An oil refinery's average demand for water is 770 gallons per barrel (42 gallons) of product, wool scouring requires from 2,000 to 15,000 gallons per 100 pounds of raw wool, and cane refining uses about 1,000 gallons per ton of sugar.

Now for a few specific water requirements from the chemical industry. It is probable that somewhere in this industry every known use of water is applied. Each individual process requires the use of water in a number of different ways and processes differ widely from one another in their volume of use.

To produce one ton of viscose rayon yarn requires between 180,000 and 200,000 gallons of water. The production of sulfuric acid involves the consumption of 4,000 gallons of water per ton of 100 percent H_2SO_4. The manufacture of rayon is a very high consumer of water, using 90,000 to 160,000 gallons per ton of product.

In general, each industry endeavors to hold the amount of water used to a minimum. For example, in the average pulp mill, the water entering the mill is used more than six times before it is discharged. In 1956, over 300 million gallons daily of water was used by the pulp and chemical industries in the State. This water supply was obtained about equally from surface and ground water sources.

CITRUS PROCESSING INDUSTRY

The Florida Citrus Commission lists 43 plants as presently producing over 95% of the concentrate juices in Florida. There are a variety of requirements for water used in the processing of citrus. For example, one study has arrived at the figure that it requires 150 gallons of water per gallon of concentrate and 40 gallons of water per case of No. 2 cans of single strength juice. But this figure may vary from as low as 78 gallons to a high of 605 gallons of water per gallon of concentrate. The average and most consistent figure would be 375 gallons of water per gallon of concentrate.

In the fresh fruit packing industry the average of 5 gallons of water per box of fruit packed is the generally accepted figure as to water utilization. At present it is estimated that all water used in the citrus processing industry is approximately 32,944.5 million gallons per season.

There are so many uses for water in Florida by industry that a complete discussion of each industry and its requirements can hardly be undertaken in this paper. I have attempted only to give you a general picture of the water requirements and utilization of three of the major users in the state.

FLORIDA'S INDUSTRIAL EXPANSION AND PROJECTED WATER UTILIZATION

Just as Florida leads all major states in the rate of population growth, so it now is the southestern front-runner in industrial growth. Business analysts agree the trend is just getting underway and that it will continue with increasing speed. In the first part of this presentation I have at-

tempted to review Florida's present industrial water requirement and utilization. We know the past, for it is a matter of record. The present is upon us, and we are experiencing it. For what the future holds we can only make projections. The reliability of our projections, will depend to a high degree upon the soundness of our known facts. These facts are the cold statistics that show how phenomenally Florida has grown in manufacturing in the past years, thus I thought you would be interested today in seeing the number of new industries and the impact that all these new plants coming into Florida has had on the state's economy. I believe we can say big business has really come to Florida this year. Altogether we know of 161 new industrial plants announced in the January-June period, and there are undoubtedly many small and some medium sized new firms which we do not yet know about. These new industrial plants will provide more than 18,000 new jobs. Employment in these new factories in related establishments announced during the January-June period, most of which are now under construction, will be the highest in the state's peace-time history when the plants are completed and put into operation. In manufacturing, the increase represents a 10% gain in employment for the state over the average 1955 level. Some of the main announcements in manufacturing in this period were two General Electric plants, five other Electronics and Electrical equipment, two American Cyanamid plants, two large cement plants and three new plants and five new operating units in the pulp and paper field.

For the period since July 1st our information is less complete, but on the basis of available data, the chances are good that a new record will again be set. The Minneapolis-Honeywell plant announced in July, the Pratt & Whitney plant in September, and Glenn L. Martin plant in October will be by themselves major additions to the state's manufacturing economy. Using this list of new and expanding industrial establishments plus additional information in the files of the Industrial Services Division of the Florida Development Commission, we have been able to approximate the water requirements of new industry in 1955. Thus, by using the data on present water utilization by industry, and the industrial growth rate for 1956, we have projected to arrive at the estimated potential water requirements by industry in the state for 1970. This represents an increase of 75 percent for the state compared to a corresponding figure of 170 percent for the United States for the same period. It is realized that estimates of this nature are highly vulnerable, since fluctuations in the national or state economy, technological developments, or other unpredictable elements may easily change the pattern upon which these estimates are based. Nevertheless, the future water requirements have been estimated through the year 1970 in this paper, and it is believed that results are indicative of the future industrial water use pattern in Florida.

In 1954, Florida stood second among all states of the union in chemical plants completed, under construction, or planned, its total being exceeded only by the state of Texas. Now 26th among the chemical producers, the Manufacturing Chemists Association predicts that Florida may move into the top ten within a few years. And with the advent of natural gas within the next two years Florida's rank as a chemical producing state may be second to none. These facts are important in any study of water requirements because the chemical industry is a "wet" processing industry consuming large quantities of water.

Another industry of which an important segment has recently been transplanted to Florida is the aviation industry. This industry has apparently taken root well in the Florida sands, and has grown and will continue to grow under the Florida sun. This industry relies heavily on the availability of skilled personnel as a plant location requirement. With the use of a specially designed presentation of case histories on Florida's ability to attract skilled personnel, the Development Commission and the State of Florida has had phenomenal success in attracting industries of this type. Through the efforts of the Development Commission, such large firms as Lockheed Aircraft, Minneapolis-Honeywell Company, and the Pratt & Whitney Division of United Aircraft have located in Florida. I would like to cite a case history of such a firm which we have helped locate in the state recently. In their criteria for a location they listed a desirable number of acres first. With their second requirement, water. They stated that their requirements are from a minimum of 10,000 to a maximum of 50,000 gallons per minute. They also stated that these water requirements must be met on a continuous basis, sixteen hours per day This water was needed for cooling purposes and did not have to be potable. After months of research involving several members of the Industrial Services Division staff, a location meeting all the stringent requirements of this manufacturer was found.

Florida's natural water resources are exceeded by no other area of equal size on the American continent. Industry has become aware of this resource as I have pointed out in citing one of the many case histories in our files. The combination of "sun and water" has attracted and will continue to attract new industry.

In summary we can say that Florida's industrial water utilization will increase 75 percent by the year 1970. This increase will represent a daily requirement of approximately 3,500 million gallons for the three major industries described in this paper.

We feel confident that with wise planning for the use of this natural resource, the future of the "Sunshine State" can be nothing but bright.

Municipal and Domestic Water Use

J. B. MILLER *

GENERAL

In a discussion of water utilization here in the state, and particularly that fraction of water resources used for municipal and domestic purposes, it seems appropriate to review briefly some factors which have been observed to affect the usage of water for these purposes. This is a field of water use where it has been possible to make some detailed observations over the country and which have been reported from time to time(1). There is a need, however, for publication of more detailed information on public water supply consumption. Many monthly or annual reports of public water systems give total recorded consumption or production, and a per capita figure may be shown, but unaccounted for water is not often stated. Sometimes water works management has made an effort to break down or analyze water consumption figures, but as a whole the water works field has not been informed as to what has been done with this and as to the results obtained.

There are several aspects of public water supply consumption or use about which it would be desirable to have more information. It would be desirable to have the per capita water use of the country, and that of the state, projected into the future if these figures were supported by necessary background data. It would be of much interest to know more about variations of the per capita water use in different areas of the country because of climatic or other factors affecting it. It is known that the residential per capita water use is affected by type of residence, by economic levels and by other conditions but there is not too much information on the extent of variations coupled to these factors. Entering into this picture of domestic water use particularly in recent years is the development, purchase and use of appliances such as automatic clothes washing and dish washing machines, garbage comminutors, and the plastic wading pools and construction of back yard swimming pools—all of which have and are increasing the use of water.

A very important factor in water use by the public or the community is the use of water at private residences for irrigation or lawn and shrubbery sprinkling. (This is increasing due to the old garden hose and nozzle being superseded by fixed sprinkler heads or perforated hose.) Another is the central type air conditioner in residences or commercial establishments which units may use water but which do not utilize cooling towers and return the water(2). These two uses of water for sprinkling and air conditioning are seasonal load increments, of course; and aside from the so-called period demand or volume use, water works people are interested in the peak demand related to these two uses. There is in turn the matter of demand charge, or the need thereof in a proper rate structure, which will affect the use of water for these purposes.

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There are, then, many overall factors affecting the use of water for municipal and domestic purposes and about which more information is needed. A few of these listed as follows will be briefly discussed here:

SOME FACTORS AFFECTING WATER USE

(a) Public purposes
  1. Cleaning streets
  2. Flushing sewers
  3. Irrigation of parks and planting areas
  4. Sewage works and water works operation
  5. Leakage
  6. Fire control

(b) Domestic irrigation

(c) Air conditioning

(d) Metering

Public Purposes

The use of water for "public" purposes, as indicated in the foregoing list, is that which is used by the several municipal departments in their functional activities or operations. Included in this category may also be the water which might be lost accidentally from time to time from the distribution system of the community, or which might be wasted through oversight or neglect. This water is often referred to as "unaccounted-for" water in relation to summary of service accounts on meter basis. In comparison with water plant total production, the unaccounted-for water should be of relatively small percentage; generally being greater for smaller or medium sized towns and of lesser percentage in larger cities.

A few figures are available on the breakdown of water for these public uses(3). One city (pop. 280,000) reports only about three-tenths of one per cent (0.28%) of its total water supply in this category. Of the total water representing this minor fraction fire control used 14.41 per cent and public service used 24.49 per cent. The water department in its operations used 1.73 per cent in chlorinating water mains, 34.42 per cent flushing mains, 5.16 per cent in cleaning reservoirs, and 1.92 per cent in settling trenches; and 17.87 per cent was lost from broken mains.

The matter of water use (or better, water loss) through leakage from pipe systems and/or tanks is something that must receive the serious consideration of water works management. Aside from leaks which occur in mains, laterals and service piping, water losses of considerable magnitude are often found occurring from pipes and fixtures on customers' premises. This water loss comes to attention because of customer complaint, particularly the cases where the loss is relatively large. A situation is reported(4) involving a small system having about 400 metered services in which a program of customer-leak detection was carried out over a period of 20 months. Using a rate-of-flow register 342 installations were covered leading to discovery of leaks at 104 houses, or 30.4 per cent of the total number. The leaks ranged from 1 gpd to 1,320 gpd. Of the 104 residential leaks, nine were quite bad (over 250 gpd) two of which wasted over 1,000 gpd; and 50 of them wasted over 25 gpd each. The total leakage observed in this small system was at a rate of

10.800 gpd or representing annual wastage of 3.942.000 gals.: which in turn represented 11.3 per cent of the entire water use of the community. The saving to the utility's customers was $1,600 per year and the good will generated is incalculable.

The "use" or loss of water through leaks in the distribution network of a city would, of course, usually be more significant than such loss on customers' premises. Moreover, such things as soil characteristics or its transmissibility, and the relative proximity of water lines to sewers, make it more difficult to detect leaking mains in the streets. Some interesting information on this subject was reported(5) from the nation's largest city as results of its most recent leak-detection campaign, stimulated by the water shortage there a few years ago. In the one-year period of 1954, 1.138 leaks were stopped which totaled 62,671,000 gpd. These leaks were found in live services, abandoned services, cellar leaks, joints in mains, broken mains, main valves, hydrant valves, and a few miscellaneous places. The smallest aggregate of waste (408,000 gpd) was attributed to the largest number (399) of single-type leaks (those involving hydrant valves). Eliminating these, the wastage averaged 84,000 gpd for the remaining types of leaks. The next largest number of leaks of a single type were those involving joints in mains, of which 292 were stopped thus saving a total of 39.469,000 gpd which was passing through joints in mains. There were only 10 broken-main leaks but they averaged 543,900 gpd of wasted water each.

It is evident that a great deal of so-called water use or loss can be controlled through the detection of leaks in mains or by an appropriate program of renovation of water mains where needed. A city of very much less population than the one just mentioned reported(6) in 1940 a water use of average 1,074,000 gpd accounted-for water and about 103,000 water "use" due to leaking mains. The leakage has been reduced materially by lining-in-place certain of the larger steel mains. Earlier in 1956 the estimated involuntary loss from the systems, including meter slippage and reservoir leakage, as well as main leakage is estimated at not over three to four per cent of the difference between production and consumption.

Water used for "public" purposes includes that which is allocated for control of fires occurring in the community. The peak demand on the water facilities in connection with this is of considerably more significance ordinarily than is the volume of water actually used. In other words, readiness to meet fire stream requirements in supplying water under adequate pressure is a more important characteristic in this fire service than is the actual volume of water used. As a case in point(7), in a city having about 90,000 population including three satelite villages and some suburban area, the general service maximum demand was 11,000 gpm, the maximum hour of this high day being 23,000 gpm; and the demand for fire protection service was an indicated 33 per cent of the total. A much smaller town of 1,500 population had a general service maximum of 548 gpm, and the results of Fire Insurance Rating Bureau tests showed maximum available fire flow was 960 gpm in the mercantile district and 620 gpm in the residential area; and the fire protection ratio used was 50 per cent. From these examples it is seen that as a general rule the demand percentages for fire stream demand increase as the population decreases.

As to the water actually used in fighting fires, the percentage of the total pumpage is very small(7); from 3 to 5 per cent usually being considered sufficient to cover the amount of water output expense chargeable to fire protection service.

Domestic Irrigation

This is a factor entering very importantly in the municipal and domestic water-use picture here in Florida. Since much of the load on water utilities here is of select character, practically all residential, and climatic conditions make for long or perpetual growing seasons, circumstances are quite good for sale of water for irrigation of lawns and shrubbery. As part of the tremendously active home construction picture in recent years, the landscaping and establishing of new lawns has resulted in use of large volumes of water for sprinkling. As a subdivision or housing development nears completion and the new lawns gain a foothold, there is some tapering off or lowering of peak demands for water in the subdivision. At least one situation is recalled in the northern part of the state, however, where a 600-house subdivision after completion had to have an additional well and pump for its water works; and the system had been designed and built to accommodate a peak demand of 350% of average, and design criteria were standard and a water rate considered equitable prevailed. The characteristics of this increment of load have received considerable attention over the country(8); and appreciable details of information on it have been developed at such localities as Long Island, N. Y.; Levittown, Pa.: Indianapolis; Kansas City, Mo.; and at Milwaukee.

Fairly close estimates of the fraction of the load occurring in residential areas attributable to lawn sprinkling can be made by correlating pumpage data for a series of high days leading up to the drop which occurs with thundershowers ending the dry spell and maximum demand days, with the pumpage data for the days immediately after or during the rainfall period. Also, in residential communities having sanitary sewerage, the difference between the sewage flow and the total water demand gives a fair approximation of the fraction of water that was used for lawn and shrubbery watering.

In six residential areas in Long Island and Levittown where highest demands are due to lawn irrigation, the ratio of maximum hour or peak demand to average annual demand are reported(8) as ranging from 4.1 to 10.0. This certainly is significant considering that for municipalities as a whole, maximum hour is normally only about 300% to 350% of annual average demand. One big city (Indianapolis) where the annual average day was about 62 mgd is reported(8) which is particularly interesting inasmuch as the water works is divided into three separate primary-pressure districts making observations possible with respect to effect of lawn sprinkling on the water demand. On the high day attributed to sprinkling the district which was mostly commercial and industrial and having minor residential load had a peak of only some 205% of the average for the day, whereas the principal residential district had a peak of slightly over 400%.

Some examples of impact of lawn sprinkling on the water supply facilities of certain areas in Florida have been reported in recent years(9). In Miami the sprinkler load has been estimated at 20 per cent of daytime demand, particularly in the dry season which of course are the winter months. For the City of North Miami the proportion of peak load considered to be for sprinkling is 25 per cent. Over on the west coast of the state at Clearwater approximately 30 per cent of the load during tourist season has been attributed to lawn sprinkling. At Bradenton there is a peak load during the months of May and June just preceding the usual rainy season in the range of 24 per cent above normal which is assumed to be due mainly to lawn sprinkling. At Orlando nearly all the peak load of 50 per cent over normal, which peak occurs in May, June and July, has been attributed to sprinkling.

Air Conditioning

Along with lawn sprinkling or domestic irrigation, water-cooled air conditioning equipment is considered in the water utilities field to represent a poor load factor. Considerable writing and reporting on the subject in relation to demand rates as well as to water use and conservation has been done. A few cities in the state have established policies or regulations in recent years designed to lessen or control the demand of these units on the water system, as well as to avoid overloading sewers, getting into such as limiting the tonnage rating of a unit that may be served without a cooling tower. Such cities reporting(10) regulations on air conditioning include Miami Beach, Pensacola and Tallahassee. A committee of the American Water Works Association has developed a model Ordinance on the subject.

Of course a very distinct difference exists between air conditioning equipment in its relationship to water use. Installations provided with conservation equipment are reported(11) to require relatively small quantities of water per day (about 5 per cent of the water required for a non-conserved unit). This type unit refers to one provided with an evaporative condenser or a tower for cooling and recirculating the water. On the other hand the "one-pass" water-cooled air conditioner uses the water a single time before wasting it to the sewer or other point of discharge. There may be perhaps only 2 gpm of water passing the condenser of the non-conserved or one-pass unit while the unit with a cooling tower may have water pass its condenser at 3 gpm. But the latter may need only about 2 per cent of this flow as new make-up water or say 0.06 gpm, as compared to the two whole gallons per minute wasted by the one-pass unit. Needless to say the effectiveness of water conservation equipment for air conditioning installations depend upon local conditions or factors such as humidity and temperature differentials possible.

One thing that has lessened the impact of the air-conditioner load increment on the community water systems in Florida is the practice where feasible of putting in private wells for source and drainage wells for discharge. The State Board of Health has issued literally hundreds of permits for drainage wells for this purpose in the Miami area alone. This is considered a very definite measure for water resources conservation, particularly in this state where air conditioning is an even more

significant factor in the use of water because of the longer or almost perpetual summer season where it has become a "must" for commercial establishments and is rapidly being classified thusly for residences. Even in another state (in the midwest) one water utility having about 120,000 accounts and serving all but about 5 or 6 per cent of its supply to residential areas reported(10) that at the end of 1953 some 12,000 tons of water-cooled air conditioning was installed among its customers. About 6,000 tons of this total doesn't have conservation equipment; and the company estimates 1,200 gals. per ton water used on a hot day so these 6,000 tons had a demand of 18 mgd on such a day and actually used more than 7 mgd.

In recognition of the fact that air conditioning is "here to say", it remains for equitable rates to be put into effect where this may be a problem and proper conservation measures taken to appropriately fit this increment into the municipal and domestic water-use picture.

Metering

The practice of metering customers' service connections is a most important factor in municipal and domestic water use. It is a very effective measure, together with a proper rate structure, in stabilizing the demand on a community or public water system. The writer has had attention called to numerous systems, some of which were relatively large, in the state in recent years where services were not metered initially and where the systems' owners suffered severe economic loss paying bills for electric energy for pumping against unstable demands resulting from flat-rate charges for water. Strangely enough many of these owners are seasoned business men in the real estate field, although new to utilities, who could not become convinced that water meters were a necessity—until extraordinary power bills for pumping brought the situation into sharp focus. Of course the high water usage where service is billed on "flat-rate" is in large part actually wastage. On many occasions the writer has driven in the rain through subdivisions before meters were installed and seen lawn sprinklers operating by the dozen while it was still raining. Not nearly so many developers attempt flat-rate water service for their subdivisions as was the case just a few years ago. Nor are there but a small number of towns in Florida where the water services are unmetered. Aside from the high energy costs for pumping the engineering design must provide for much greater pumping capacity and larger pipe for distribution network, for systems where services will not be metered.

Water works literature is replete with reports indicating the benefits accruing from the pactice of metering and showing its effect on water consumption. Here a distinction should be made between water consumed (or used for a gainful purpose) and water that is wasted. The fact is, water wastage is greatly reduced or virtually stopped by metering, while consumption or proper use is put on a fair basis. Perhaps a typical situation reported(12) concerns a fairly small town which, before metering the customers' services, was pumping some 660,000 gpd to 830,000 gpd down through the year. After the metering was completed the pumpage leveled off to a range of 333,000 gpd to 466,000 gpd, or a reduction of close to 50 per cent. This compares favorably with a reduction of

per capita water use of 135 gpd average before metering down to average 75 gpd per capita after metering, or about 45 per cent reduction. It should be mentioned too that there was a 33% reduction in power cost for the water plant, which benefited the taxpayers of the town.

PUBLIC WATER SYSTEMS IN FLORIDA

The facilities for supplying and serving water to the public in Florida have shown a very considerable growth in recent years, both in scope and number. Since this is a primary public health utility, it is not at all surprising that its expansion curve is geared almost directly to the population growth curve of the state. Some data on the past situation

PUBLIC WATER SYSTEMS IN FLORIDA *

(SOURCE OF SUPPLY)

Primary Source	Number of Systems				Estimated Population Served			
	1945	% of Total	1956	% of Total	1945	% of Total	1956	% of Total
Wells	221	90.0%	473	95.4%	1,070,000	78.7%	2,472,000	83.9%
Lakes	12	4.8%	14	2.8%	120,000	8.8%	216,000	7.4%
Springs, Rivers, etc.	13	5.2%	9	1.8%	170,000	12.5%	260,000	8.7%
Totals	246	100.0%	496	100.0%	1,360,000	100.0%	2,948,000	100.0%

Population of Florida	2,250,000	3,761,000 (Est.)
Per cent of total population served	60.5%	78.5%
Total water use	130.00 ± MGD	388.3 MGD
Average per capita water use	95 GPD	131 GPD

(TYPE OF TREATMENT)—1956

Type of Treatment for Majority of Water Distributed to System	Number of Systems	% of Total	Population Served	% of Total
None	152	30.7	155,000	5.27
Chlorination only	128	25.8	354,000	12.10
Aerate and chlorinate	110	22.2	639,000	21.60
Other treatment without chlorine (aeration, stabilization, etc.)	28	5.6	58,000	1.97
Zeolite softening	10	2.0	105,000	3.56
Filter plants	68	13.7	1,637,000	55.50
Totals	496	100.0	2,948,000	100.00

* From unpublished data (Records of Bureau of Sanitary Eng., Fla. State Bd. of Health) November 1956.

for a quick and brief comparison with the present are given herein, using figures on numbers and types of plants and systems and populations or estimates of this factor. (Perhaps it would be well to mention that Florida statutes define a public water supply as any system serving more than 25 inhabitants. The figures discussed here, however, relate to systems serving 100 or more people or having about 30 to 35 service taps or connections.)

The(13) table of data are rather self explanatory; and they reflect the changes which have taken place in the public water works picture in Florida for the approximate decade which they cover showing the current status of these facilities. For one thing, the data show that in the decade the population served was more than doubled. Also, the data show an increase in per capita water use in the central systems serving the public from 95 gpd in 1945 to 131 gpd as of this year. This is representative of an annual increase of about 2.8 per cent above the previous year, commencing with 1945. It is interesting to note the comparison with an annual increase of 2.4 per cent which was the estimated water consumption increase to 1960 published(14) by the American Public Works Association as a result of its 1949 survey covering 27 water supplies over the country. The annual increase in per capita water use, and the increasing number of consumers combine to form a factor which is significant in the relationship of municipal and domestic water use in the management of water resources.

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Recreational Water Use Values

H. R. Wilber, M.D.*

There has long been a need in Florida for an estimate of the financial remuneration arising from recreational use of our waters. It has been my privilege to work on such a project for the past several months in connection with Florida's Water Resource Study Commission. The findings of this hard working body will be used by the Legislature to guide it in governing all water uses and planning. The following is no part of that report, but a summary of some startling facts, obtained by me, as we studied various recreational water uses in the State. While we had originally planned to have several articles to cover this study, our cost and space limitation forced one fused article to be used. I want to give full praises to James Counselman of The Florida Game and Fresh Water Commission, T. N. "Tommy" Anderson, Editor and commentator of Eustis and to various members of the Department of Conservation staff for the efforts they expended. Each persented a full article, which I have been forced to coalesce as best I could.

Recreational Boating figures cover everything above a rowboat and include larger yachts using the Inland-waterways, bays, lagoons, lakes, etc., of the whole State. Documentary evidence from such outstanding sources as the National Association of Engine and Boat Manufacturers, Inc., of New York, Outboard Boating Club of America, U. S. Coast Guard and findings from seventy-five inquiries to boat, engine, trailer, equipment and fuel sources of the country is on file. A projected minimal total value of recreational boating to the economy of Florida produces the startling figure of $255,000,000.00.

There were some 400,000 boats using the waters of Florida in 1954 whose average annual operative cost was estimated at the low figure of $500.00 each, covering depreciation, taxes, housing, insurance, transportation, fuel and related boat equipment. This yields the amazing figure of $200,000,000.00 for the year. Outboard boats and motors in '55 supplied 40% of the dollar value of newly purchased equipment and was divided as follows: $6,500,000.00 was spent for new motors and $13,000,000.00 for boats and equipment to use therewith. The operating cost of new outboard outfits for 1955 amounted to $5,000,000.00. Thus a surprising total of nearly $25,000,000.00 is attributed to new outboard boating use in 1955. Inboard boats, ranging from dinghies to yachts, supplied 60% of dollar value of newly purchased equipment or $30,000,000.00; figuring after the same fashion as that used in outboard calculations. These figures will yield the surprising total of $255,000,000.00.

It is of interest to note that 8,860,000 gallons of gas was used in outboard engines and 9,515,000 gallons in inboard engines and at the prevailing gas tax of the State produced over $1,250,000.00 for highway uses, while never being consumed thereon and returned little benefit to those paying said tax. Also used were 755,000 gallons of lubricating oil and 1,772,000 gallons of Diesel Fuel.

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With the rate of increased usage being 10% per year, the care of this State asset is imperative to our welfare. At present, boating receives little or no government support or control. Now since the advent of superspeed motors on light equipment definite safety controls are a coming necessity.

Salt Water Recreational Fishing in Florida stands unique among the states of the Nation, in that Florida has within its salt water area one of the most popular salt water recreation sites as well as prominent commercial industry. Probably no other state has such splendid facilities for both activities.

For the present, let us consider only the recreational aspects.

Florida has thirty-five counties facing salt water. In all of these boating, fishing and bathing are available. A salubrious climate makes these activities possible, during all of the year, in most of the counties, while in others such sport is only restricted during a few of the winter months.

Although the vast number of boats used makes universal licensing extremely difficult, and although in the densely populated areas the transient nature of many of the boats results in their not being listed with the department, the figures are still impressive.

During the past fiscal year (July 1, 1955 - June 30, 1956) there were licensed, for pleasure, 5,452 boats of various sizes. In addition, there were 5,724 boats available for hire during the same period. The latter were also of various sizes and were available to take from four to sixty persons each into the salt waters to fish. These licenses are not only for boats owned and operated by Florida citizens. Many of them belong to nationwide enthusiasts, including several from California.

The Conservation Department, cognizant of the vastness of salt water recreation in the State, initiated studies, almost a year ago, to determine how many people in Florida fish, how much each fisherman spends each year, how many fish are caught by sportsmen, what percentage of visitors and residents come to Florida to fish, and many other facts concerning the fishing fraternity. This study will not be finished until February, 1957.

As the complete picture comes more into focus, it may be shown that, next to the weather, Florida's greatest asset is the recreational use of salt water. A few years ago Sportsfishermen made a comprehensive study of money expended each year by those fishing in salt waters of Florida. What, at that time was viewed as erroneous, when it was stated to be $600,000,000.00, is now becoming validated. In the comprehensive study being conducted for the Department of Conservation by Miami Marine Laboratory, with I. B. M. accuracy, every figure, at this stage, points to a total well in excess of $600,000.000.00. This is indeed the greatest value among all Florida income sources.

The Game and Fresh Water Fish Commission, operating at the sole expense of Sportsfishermen, is running a two million dollar business. The recreational water use, falling under their control in 1955, totalled an astounding $125,000,000.00. I wish to remind you that there are no State funds being expended for aiding and assuring the health of such a vast business whose economic impact falls upon the whole of the State's population. Only by wise Legislative assistance can this vast asset continue, under the annually increasing demands of growing population and

tourism. Pollution increases with population and industry, and each of them cut deep inroads into our waters' productivity, thus lessening supply of fish and game. Also new population, industry and tourism are now concentrating, more than ever before, on the inland areas of the the State. Here they will be increasing demands upon fresh water. "Supply and Demand" being a basic law of Nature, we must pause and plan to perpetuate our resource.

Commission figures indicate an expenditure for fresh water fishing of 121.514.000.00. Licenses were issued to 329.864 fishermen, while a like number fished, in the county of their residence, without license. It is my personal feeling, that laws permitting free fishing should be matched by laws creating subsidy for same: since our Commission spends as much of the Sportsman's money for the benefit of unlicensed as for licensed fishermen throughout the State.

Besides fishing, recreational use of fresh water is reflected in incomes from various other sources under study, *i.e.*, airboats $1,036,000.00, waterfowl hunting $1.500,000.00, water skiing $429,000.00, frog hunting $1,362,000.00, and the bait industry $726,000.00. Excluding motels and private dwellings, there is a capital investment of $3,500,000.00 in fish camps alone on lakes and streams of Florida.

Various facts become obvious from the foregoing statements. Recreational water use is the biggest industry in Florida and yields the biggest total income. This income totals over $1,000,000,000.00 per year. Such things as lodging, food, transportation, gasoline, etc., being kindred income producers, are responsible for much more. It becomes of great importance when compared with the annual income from the Citrus Industry, which is $365,500,000.00, the Power Industry at $175,000,000.00 and the Pulp and Paper Industry at $255,000,000.00.

Conclusions reached after above study would seem to indicate much need for thought. At an annual pressure increase of ten percent per year, we can hardly harvest our crop as we did the buffalo of the early United States, without thought to Conservation of our asset. Our Legislative and Executive leaders must become conversant with the facts and figures involved in this State's economy through Recreational Water Use. They should apply this knowledge to the protection of this asset when considering such legislation as: water use, pollution, subsides, etc. For instance, tax on gasoline used on water transportation only, should be used for the improvement of facilities on water. Such facilities are hyacinth control, launching sites, marinas, channel control and maintenance of fishing and hunting at a level sufficiently high to meet increasing demands. Of greatest need at present are new laws producing income for our control agencies; such laws covering transfer of funds and new license structure encompassing all users.

In this day of Florida's industrial consciousness no new or old industry should be permitted any privilege which would in any way affect this great asset adversely. The NEED of the care of so great an asset is equalled only by the NEGLECT of the asset by administrative bodies of the State. Sunshine and rain will certainly be with us forever, but failure to protect the bounty of their production will surely reflect in loss and sadness to all.

The Utilization of Water by Agriculture in Florida

J. Mostella Myers and Thomas C. Skinner *

The major agricultural water requirement of Florida is the water needed on agricultural lands for profitable crop production. In Florida, water is supplied to crop land principally by precipitation; however, irrigation is supplying an increasing amount each year. Average annual precipitation corresponds closely to the annual potential evaporization. However, because large amounts of water run off the surface during heavy rains and since the soil cannot retain for plant use all the water that is absorbed during periods of excessive rainfall, supplemental water is required for optimum production. The inefficiency of normal precipitation can be illustrated by citing climatological data gathered at Gainesville by McCloud(1), and presented in Table 1.

TABLE 1.—Climatological Data, Gainesville, Florida.

Time	Precipitation	Estimated Potential Evapotranspiration*	Drought Days	Crop-Water Deficit**
Jan. 1—Sept. 30, 1955	38.97	60.15	122	26.13
Jan. 1—Sept. 30, 1956	42.21	53.96	103	17.60
Jan. 1—Sept. 30, (51 Yr. Avg.)	42.26	....	......	....

* Based on McCloud's(2) evapotranspiration formula.

** Deficit based on a two-inch available water storage, using the daily water budget and McCloud's(2) evapotranspiration formula.

Precipitation during the first 9 months of 1956 was 42.21 inches. This amount is only .05 inch less than the 51-year average, yet there were 103 drought days, and a crop-water deficit of 17.60 inches. The estimated potential evapotranspiration during the period was 53.96 inches, indicating that the 103 days of drought would not have occurred had the rainfall been supplemented with 11.75 inches of irrigation water. This is only true when rainfall and irrigation are 100 per cent efficient; that is, none of the precipitation or irrigation water percolated through the plant root zone or can be credited to surface run-off. This degree of efficiency, of course, is improbable. Actually, for the 9-month period, it was estimated that 5.85 inches (17.60 inches of crop water deficit less 11.75 inches difference between potential evaporation and precipitation) of precipitation either leached through the soil root zone or ran off the surface of the soil. Efficiency during the application of irrigation water is highly

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variable, depending on the method of application and weather conditions. If an irrigation efficiency of 70 per cent, which is considered average, is used, it is estimated that 25.20 inches of irrigation water would have been needed in addition to rainfall to meet the water requirements of a crop growing during the first 9 months of 1956. This is a large amount of water when it is considered that rainfall during the period involved very nearly equaled the 51-year average.

In order to appreciate the utilization of water by agriculture, it is helpful to have an understanding of the evapotranspiration concept. Evapotranspiration is the total quantity of water evaporated from the soil and moved by transpiration through the plants. For an irrigated field evapotranspiration represents interception, soil moisture evaporation and transpiration by crop plants and accompanying weed growths, plus evaporation that takes place during irrigation.

In 1944, Thornwaite proposed a distinction between actual evapotranspiration and potential evapotranspiration(3). He defined the latter as the water loss that would take place if the soil contained sufficient moisture for plant growth at all times. Potential evapotranspiration coincides closely with the actual water requirements for most crops and is the basis for estimating the irrigation water needs for agriculture presented in this report.

Data on agricultural land use are presented because they so vitally influence agricultural water use. There are approximately 35,000,000 acres of land in Florida. About one-half of the total land area is in farm-land and approximately 25 per cent of the farm-land is devoted to the production of improved pasture, field crops, citrus and truck crops. It is estimated that more than 820,000 of the 4,276,000 acres planted, to these four crops, was irrigated in 1956. Table 2 shows the acres planted to major crops, as reported by 1954 agricultural census, and the acreages of these crops that were irrigated in 1956. The source for the latter information is a survey made by Mr. T. C. Skinner(4), with the assistance of the county agricultural agents. The 1954 census of agriculture indicates that approximately 428,000 acres of crops were irrigated in 1954 and the Skinner Survey shows that irrigated acreages had increased to more than 820,000 by 1956. This represents a sizeable increase in irrigated acreage for a two-year period during which it is estimated that only a slight increase was made in the acreage planted to these crops. If there was no change in acreages planted to the crops listed in Table 2—irrigated acreages increased from 10.0 per cent of the total planted in 1954 to 19.2 per cent in 1956.

Data on the amount of water utilized for irrigation purposes in Florida are not available; however, information on potential evapotranspiration and rainfall is available and may be used in making reliable estimates of agricultural water use. For this report, irrigation water requirements are based on computations of the difference between the net soil moisture supplied by rainfall and potential evapotranspiration demands resulting from the solar energy available. To add precision to the estimates, the state was divided into 6 sections having similar rainfall characteristics and 3 locations were selected for solar energy values. Median rainfall by divisions and potential evapotranspiration by locations are shown in Tables 3 and 4 respectively. Irrigated crop acreages were divided into

TABLE 2.—CROP ACREAGE AND IRRIGATED ACREAGE FOR CERTAIN CROPS GROWN IN FLORIDA 1954-56.

(All Figures Except Per Cent Are in 1,000 Acres)

Crop	Total Acres 1954[1]	Acres Irrigated 1956[2]	Per Cent Irrigated
Improved Pasture	1,923	210	9.2
Field[3]	1,470	......	......
(a) Tobacco	30	9	33.3
Citrus	565	242	42.8
Vegetables and Truck	321	273	85.0
Other[4]	......	86	......
Total	4,279	820	19.2

[1] Source: 1954 Census of Agriculture (Preliminary).

[2] Source: Survey of county agents made by T. C. Skinner(4), Florida Agricultural Extension Service, 1956.

[3] Tobacco Acreage included—Insignificant acreage other than tobacco irrigated.

[4] Includes small acreages of Field Crops, nursery and greenhouse products, Flowers, etc.

TABLE 3.—MONTHLY MEDIAN RAINFALL 1931-1956 FOR VARIOUS SECTIONS OF FLORIDA.[1]

Month	Median Rainfall in Inches by Sections					
	North West[2]	North[3]	North Central[4]	South Central[5]	South West[6]	Lower East Coast[7]
January	3.33	2.61	1.32	1.37	1.00	1.81
February	3.45	2.58	2.46	1.88	1.58	1.82
March	5.06	2.99	3.22	3.08	2.14	2.54
April	4.34	2.68	3.16	2.92	2.97	3.62
May	3.69	2.58	3.41	3.21	3.74	3.94
June	5.44	6.05	7.22	7.06	7.96	6.78
July	7.79	7.71	8.42	8.05	8.28	6.44
August	6.54	6.56	7.22	6.76	7.12	6.69
September	5.37	6.88	6.40	6.72	7.73	7.58
October	1.52	3.80	3.76	3.34	3.82	8.32
November	2.44	1.46	1.45	1.38	1.30	2.27
December	3.71	2.36	1.80	1.63	1.22	1.50

[1] Information furnished by Mr. Keith Butson(5), State Climatologist, Florida Weather Bureau.

[2] Counties—Bay, Calhoun, Escambia, Franklin, Gadsden, Gulf, Holmes, Jackson, Jefferson, Leon, Liberty, Okaloosa, Santa Rosa, Wakulla, Walton and Washington.

[3] Counties—Alachua, Baker, Bradford, Clay, Columbia, Dixie, Duval, Flagler, Gilchrist, Hamilton, Lafayette, Levy, Madison, Nassau, Putnam, St. Johns, Suwannee, Taylor and Union.

[4] Counties—Citrus, Hernando, Lake, Marion, Orange, Pasco, Seminole, Sumter and Volusia.

[5] Counties—Brevard, DeSoto, Hardee, Highlands, Hillsboro, Indian River, Manatee, Okeechobee, Osceola, Pinellas, Polk, St. Lucie and Sarasota.

[6] Counties—Charlotte, Collier, Glades, Hendry, Lee, Martin, Monroe and Palm Beach.

[7] Counties—Broward and Dade.

TABLE 4.—ESTIMATED MONTHLY EVAPOTRANSPIRATION BASED ON NET SOLAR ENERGY.*

Month	Potential Evapotranspiration Inches of Water (a) Gainesville	(b) Central Florida**	(a) Miami
January	2.98	3.63	4.27
February	3.47	3.82	4.17
March	4.94	5.64	6.34
April	6.13	6.25	6.38
May	6.17	6.39	6.61
June	6.77	6.22	5.67
July	6.07	5.85	5.63
August	6.23	6.10	5.97
September	5.74	5.62	5.50
October	4.74	4.81	4.88
November	3.49	3.83	4.17
December	2.64	3.04	3.43

* Data furnished by Dr. D. E. McCloud (1), Associate Agronomist, Agricultural Experiment Station.

** Average of potential evapotranspiration at Gainesville and Miami.

TABLE 5.—LENGTH AND TIME OF CROP GROWING SEASON BY SECTIONS.
Section of Florida

Crop	North West	North	North Central	South Central	South West	Lower East Coast
Citrus	xxxxx	xxxxx	12 Months	xxxxx	xxxxx	xxxxx
Vegetable and Truck	3 Months Mar.-May	3 Months Mar.-May	3 Months Feb.-Apr.	3 Months Feb.-Apr.	3 Months Jan.-Mar.	3 Months Jan.-Mar.
Tobacco	3 Months Apr.-June	3 Months Apr.-June	xxxxx xxxxx	xxxxx xxxxx	xxxxx xxxxx	xxxxx xxxxx
Pasture	8 Months Feb.-Sept.	8 Months Feb.-Sept.	10 Months Jan.-Oct.	10 Months Jan.-Oct.	12 Months	12 Months
Other*	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx	xxxxx

* Growing season variable.

TABLE 6.—ESTIMATED ANNUAL DEPTH OF SUPPLEMENTAL IRRIGATION WATER NEEDED FOR AGRICULTURAL CROPS.
(All Values Are in Inches)

Crop	North West	North	North Central	South Central	South West	Lower East Coast
Citrus			13.4			
Vegetable and Truck	8.4	11.4	9.2	10.1	11.8	10.6
Tobacco	11.4	11.4				
Pasture	16.7	19.1	21.5	23.2	28.0	25.6
Other	12.2	12.2	12.2	12.2	12.2	12.2

five groups: (1) citrus, (2) vegetable and truck, (3) tobacco, (4) pasture and (5) "other" and growing seasons were established for each crop in each of the 6 sections of the state, and are tabulated in Table 5.

A rainfall efficiency of 90 per cent was used for citrus because the extensive root system of this crop reduces the likelihood of soil moisture percolating to a depth below the root zone and the nature of the soil on which most citrus is grown is not conducive to run-off. For all other crops, 80 per cent efficiency was used for months with median rainfall of less than 4 inches and 70 per cent for months with a larger median rainfall. This group of crops are shallower rooted than citrus, thereby increasing the possibility of water loss by deep percolation. The lower efficiency allowed for months with heavy rainfall is due to the increased possibility of run-off and deep percolation.

In determining the difference between median rainfall and potential evapotranspiration, it was assumed that the potential evapotranspiration at Gainesville was representative for Northwest and North Florida; the potential evapotranspiration in Central Florida was representative for North Central and South Central Florida; and the potential evapotranspiration for Miami was representative for Southwest and the Lower East Coast of Florida.

Computations, based on the procedures described in the above paragraphs and in consideration of data in Tables 3, 4, and 5, give the estimated depths of supplemental irrigation water needed for crops in various sections of the State. These estimates are tabulated in Table 6.

The estimated supplemental irrigation water requirements for Florida in 1956 are computed by applying the depths (Table 6) to irrigated acres (Table 2), and are presented in Table 7. The 1,042,000 acre feet shown in Table 7, is enough water to cover the entire area of Polk County to a depth of approximately 1 foot.

Other interesting aspects of the supplemental use of water by agricultural crops are the types of irragtion systems in operation and the sources of irrigation water. Skinner's(4) Survey shows that in 1956 there were approximately 16,000 irrigation systems in operation in Florida. They were classified as to type of system with approximately 60 per cent being portable, 35 per cent open ditch, mole drain and seepage ditch, 1 per cent underground tile,[1] and 4 per cent overhead oscilating pipe. One-third of the portable systems distributed water through rotary sprinklers and the remainder distributed water through perforated pipe. It should be noted that these percentages do not reflect as to acreages.

Forty-one per cent of the irrigation systems in Florida used deep wells, 27 per cent shallow wells and 13 per cent "other" as a source of supply for irrigation water. These percentages probably bear little relationship to acreages.

The present annual water requirement for agricultural crops is estimated to be more than 15 million acre feet. Of this amount, less than 1.5 per cent is supplied to the crops by supplemental irrigation. When the increased economic benefits to agriculture that can be attributed to irrigation are weighed against the relatively small amount of water involved, there is little doubt as to the economic feasibility of irrigation in agriculture. The increasing rate to which this farming practice is put

[1] Underground tile systems in Seminole County not included in Skinner's report.

into operation on Florida farms justifies the predictions of many agricultural leaders that irrigation is still in its infancy in Florida.

TABLE 7.—Estimated Supplemental Irrigation Water Requirement for Crops in Florida—1956.

Crop	Acre Feet (Thousands per Year)
Citrus	261
Vegetables and Truck	232
Tobacco	9
Pasture	453
Other	87
Total	1,042

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Some Economic Aspects of Formulating Water Policy

W. K. McPherson *

In a period of less than two weeks Florida's major daily newspapers carried two series of stories about water. One series consisted of accounts of a flood in the Kissimmee River Valley, particularly in the vicinity of the towns of Kissimmee and St. Cloud. Because of extensive crop and property damage caused by this flood, the Federal government responded favorably to a request for financial assistance. The other series reported the fact that the water table in much of the state had fallen to dangerously low levels and that the state should establish a definite policy with respect to water utilization. Whereas the first group of stories indicated that there was more water available than could be used, the latter suggested that water was becoming a scarce good. The fact that these two apparently different situations could exist in peninsular Florida at the same time clearly suggests that there is some confusion on what constitutes an adequate supply of water.

Before the adequacy of the supply of water can be scientifically evaluated, the word water and/or phrases describing different kinds of water must be defined precisely. Scientists define water as being the liquid form of the chemical compound H_2O. On the other hand, the word water is often used to identify sea water, an aqueous solution made up of 97 or more percent H_2O. Between these two extremes are numerous aqueous solutions and suspensions that are commonly called water. In this paper the phrase "water resources" is used to identify all liquids comprised of 97 or more percent H_2O, regardless of the nature of the substances held in solution and/or suspension. The phrase "water products" is defined as being the specific kinds of water that are useful to human beings. Water products are generally identified by modifying the word water with a descriptive adjective. For example: sea water, distilled water, irrigation water, boiler water, and drinking water are all water products at particular times and particular places. This definitional framework makes it possible to evaluate the adequacy of the supply of various kinds of water.

The amount of water resources available for human use has not been measured accurately. However, these resources do cover more than two-thirds of the earth's surface to an average depth of several thousand feet. Furthermore, the amount of water resources available does not change appreciably with use. At the present time the world's supply of water resources appears to be sufficiently large to permit the rapidly increasing human population to use it freely in the foreseeable future. As long as this is true, there is no reason for people to be concerned about any scarcity of water resources.

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The task of evaluating the supply of water products available for human use is complex because (1) water resources can be converted into water products by a wide variety of methods, and (2) each of the numerous water products can be and frequently is produced in different quantities. The impact of these factors on the supply of water products will be examined separately.

The most unique characteristic of the world's supply of water products is that the human race inherited a gigantic facility for converting water resources into water products in the form of the hydrologic cycle. This cycle is a capital good that utilizes energy from the sun to (1) adjust the quality characteristics of water resources, (2) establish a temporal distribution of water products, and (3) transport water products from place to place.

The evaporation phase of this capital facility can convert water resources into water products at the rate of about 80,000 [1] cubic miles annually. About 24,000 cubic miles of these products are delivered to the land surfaces of the earth in the form of precipitation. An average of about 144,697,900 acre feet of these water products is delivered to the state of Florida each year.[2] In other words, Florida receives an average of about 129,177 million gallons of fresh water daily. Of this potential supply of water products, only about 3,700 million gallons per day [3] or less than 3 percent of the amount available is utilized. Clearly then the hydrologic cycle produces an ample supply of water with desirable quality characteristics to support a much larger population providing facilities are made available to deliver it at the time and place it is needed. Thus, it is the facilities used to produce water that are scarce rather than water *per se*.

In primitive societies, when people wanted to use more water it was necessary for them to move to places at which the hydrologic cycle produced a larger volume of water with quality characteristics desired and to be there when the cycle made it available. In other words, man had no control over the capital facilities for manufacturing water products that were provided by nature.

Humans soon found that by altering and augmenting the hydrologic cycle they could have a more stable supply of such products as water that could be used for domestic purposes. By cleaning out springs, by digging wells and canals, and by building reservoirs and dykes, people added to the capital facilities that produced water products. In addition to augmenting the cycle with facilities to expand its capacity to produce water of desirable quality characteristics at specific locations at particular times, capital facilities have also been added to restore the desirable quality

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[1] William C. Ackerman, E. A. Coleman, and Harold O. Ogresky, *Water—The Year Book of Agriculture, 1955* (Washington: U. S. Government Printing Office), p. 41.

[2] Calculated from an assumption that an average 50 inches of rain falls annually on 34,727,500 square acres of land surface. Actually the estimate of 900 cubic miles of water products is low because the amount of water the hydrologic cycle delivers in the form of such things as fog, mist and dew are not taken into consideration. Theoretically this could be the equivalent of about 15 inches of rain. See F. W. Went, *ibid.*, p. 104.

[3] Preliminary report of the Committee on Water Use of the Water Resources Study Commission. (Gainesville, Florida: 1956), unpublished.

characteristics of water after it has been used for such purposes as the transportation of human and industrial wastes. Municipal and industrial water treatment plants are illustrations of this kind of facility. Facilities that alter and expand the hydrologic cycle (1) make it possible for people to live in closer proximity to each other and (2) reduce the need for people to move from place to place to obtain more water.

As early as the fourth millenium B.C. Eastern civilization had extended the usefulness of the hydrologic cycle with ditches and dykes and maintained an effective control of water for more than five thousand years.[4] The fact that population densities in the earlier Oriental, Greek, and Egyptian civilizations approached those that prevail today suggests the extent to which water control can contribute to social and economic growth.

In the Eastern United States and particularly in Florida the hydrologic cycle has produced such a large volume of water products that supply of water has not yet limited the state's economic growth seriously. In sharp contrast, economic growth in such areas as Western United States and Northern Africa has been curtailed by the scarcity of facilities to produce water when and where humans want to use it.

The human race has now accumulated sufficient technical knowledge to increase the productivity of the hydrologic cycle and thus make it support much larger populations and levels of economic activity in both the humid and desert areas. Western civilization is just now beginning to combine the technologies upon which hydraulic and industrial civilizations are based. How much population growth and how high a level of living this combination of technologies will permit is not yet known.

To combine the industrial and hydraulic technologies, it will be necessary to erect many new structures and operate them in conjunction with the hydrologic cycle. To do this people must invest substantial amounts of money. When deciding whether or not to make an investment of this kind, people consider (a) the type of organization they want to use to manage the investment and (b) the return the investment is expected to produce.

In the past, individuals and private organizations have assumed much of the responsibility for erecting and operating facilities that convert water resources into water products. Private funds have been invested in capital water facilities when it has been possible to estimate the value of water products accurately enough to justify the cost of construction. Large manufacturing firms have been able to estimate the value of a gallon of boiler water quite accurately. Farmers have invested in wells, drainage facilities, and ponds when it was obvious that the benefits from such facilities would exceed the cost. However, farmers have not had the data needed to estimate the increases in revenue that will result from particular investments in capital water facilities and particularly major investments in reservoirs and canals.

Traditionally, domestic water supplies have been produced either with publicly owned and operated facilities or by privately owned firms operating as public utilities under the supervision of boards or commissions. The development of this method of producing water products can be

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[4] Karl A. Wittfogel, "Hydraulic Civilizations," *Symposium: Man's Role in Changing the Face of the Earth* (Princeton, New Jersey: June 16-22, 1955).

attributed to (1) the fact that a single firm can produce domestic water products more economically than numerous firms and (2) the reluctance of the American people to give any one individual or private firm enough economic power to set the price of a commodity without some supervision.

During the past half century[5] both farmers and industrialists have been becoming increasingly reluctant to assume all of the responsibility for making investments in water-producing facilities because (1) the rights to use water resources that are partially converted to water products are not defined with sufficient precision to justify capital investment that must be amortized over a long period of time,[6] (2) investments of the magnitude needed to control water frequently cannot be justified to produce the volume water products that can be used by only one individual or firm, (3) multipurpose facilities are frequently more economical to construct than single purpose structures, but one firm is seldom able to make full utilization of the water produced, and (4) to manage water efficiently, all of the uses that are made of water in entire watersheds must be integrated.[7] Consequently, there has been a tendency toward a more extensive use of public agencies to produce and manage water.

By using public agencies as the media for investing money in capital water-producing facilities, people, acting through their elected representatives, can place a value on facilities even though it cannot be measured quantitatively. For instance, even though it is not yet possible to place a dollars and cents value on the maintenance of a river or a lake for recreational uses, the public is willing to make a rough approximation of this value through political channels and back it up by investing public funds to obtain these values. Likewise, large sums of public funds are invested in facilities for producing irrigation water without any very accurate data on how much an inch of water applied at any particular time will increase the yield of specific crops. Finally, the problem of measuring the anticipated returns from any particular investment in water is further complicated by the fact that one facilitiy can produce water that can be used for many purposes and thus have many values. Without a knowledge of precisely how the water would be used, its value could not be estimated even though its value for each purpose was known. Scientists can contribute much to making the construction of capital water structures an attractive investment for private funds by obtaining the data needed to establish the value of water more accurately.

When the need for expanding the capacity of the hydrologic cycle appeared, the most economical structures were constructed first. As time passed it became apparent that the potential capacity of the cycle could only be realized by relating the man-made structures to its natural components. In other words, it became obvious that the canals and dams should be related to watersheds, aquifiers, and underground streams. In most instances these more extensive alterations in the cycle call for larger capital investments and frequently facilities that are more expensive to

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[5] The Reclamation Act of 1902 was a first major expression of this trend of thought.

[6] John F. Timmons, "Problems in Water Use and Control," *Iowa Law Review*, Vol. 41, No. 2 (Winter 1956), p. 178.

[7] Roy E. Huffman, *Water, op. cit.*, page 67 recognizes the last two of these factors: the multipurpose and the watershed concepts.

operate than those currently used. The public is hesitating to make some of these investments until they have more accurate estimates of the benefits that will accrue from alternative water-producing facilities. The magnitude of the public interest in making water resources more useful is clearly demonstrated by the fact that four presidential commissions [8] and numerous state water studies have been initiated in the past 10 years. The primary objective of most, if not all, of these studies was to provide a basis for formulating public policy with respect to the use of water.

To date, no clear-cut national policy with respect to the production of water has yet emerged. In some of the major watersheds such as the Tennessee and Columbia Rivers, rather definite water policies are now being formulated. Water policy in the Western states, and especially where the capacity of the hydrologic cycle is as little as six inches of precipitation annually, is much more clearly defined than in the states where the cycle is more productive. However, current proposals to expand the productivity of the hydrologic cycle are being evaluated on an *ad hoc* basis—largely with qualitative rather than quantitative information.

Why is it so difficult to formulate public policy with respect to the use of water? A general review of several current studies indicates that there is rather general agreement on the following propositions: (1) quantitative hydrologic data are inadequate, (2) property rights in water are not clearly defined, and (3) values of water products for many purposes are not established. These propositions will be examined in more detail.

(1) Physical data on the rate at which the hydrologic cycle produces water products of specified quality characteristics at particular times and particular places are needed to make accurate evaluations of its capacity and the extent to which it can be expanded. Data on such things as precipitation, the capacity of ground water storages and the rates of flow and the water-holding capacity of the soil that is available [9] is of excellent quality but does not describe enough situations to enable engineers to design and operate the kind of structures that will increase the productivity of the hydrologic cycle. This situation can be corrected by (a) increasing appropriations to the several agencies now collecting portions of these data and/or (b) establishing new agencies to do a more comprehensive job of collecting data on water.

(2) Property rights in water must be defined with sufficient precision to provide the stability needed to justify investments in capital facilities that can be amortized over long periods of time. During the past decade, excellent studies of national and state water laws have been made. It is generally agreed that more comprehensive water laws should be enacted. Unfortunately, most of the discussion on the nature of such legislation has centered around the relative merits of the riparian and prior appropriation doctrines of water law. There is much evidence indicating that neither of these doctrines provide an adequate basis for establishing the kind of rights that will extend the usefulness of water products and facilitate their evaluation in the market place. In establishing new water

[8] The President's Water Resources Policy Commission, the President's Material Policy Commission, the President's Missouri Basin Survey Commission and the Commission on Organization of the Executive Branch of the Government.

[9] William E. Hialt and Robert W. Schloemer, *Water, op. cit.*, pp. 78-84.

rights to extend the usefulness of water, the existing rights in water should be recognized.

(3) Much of the data needed to accurately determine the economic value of water when used for different purposes is not available. Data upon which the value of domestic water is determined and the method of determining it is reasonably satisfactory. Likewise, industrial engineers are able to estimate the economic value of water in manufacturing operations with some degree of precision.

In sharp contrast, the economic value of adding an inch of water to specific farm crops when they are growing, and the value of withdrawing an inch of water during floods has not been established with sufficient precision to help people evaluate the desirability of constructing water control facilities. Neither has the economic value of water used for recreational purposes been established. Since the largest single use of water in the country is for the irrigation of agricultural crops and the economic importance of recreation is increasing rapidly, this deficiency in data is extremely important.

Data of this type is particularly important to the economic well-being of Floridians because it is entirely possible that when they do become available it will be obvious that investment in water-producing facilities in humid areas will be more attractive than investments in similar facilities in arid and semi-arid areas. An early investigation along these lines suggests that the cost of improving land in the Columbia River Basin of Central Washington was about seven and one-half times more than the cost of improving the same acreage of land in three Southern Virginia counties.[10] Similar studies comparing the cost of reclaiming land in the West and in peninsular Florida might well show an even higher ratio since (1) Florida land is relatively level and (2) the water from both surface and ground sources can be controlled rather economically. More studies of the type reported at the Symposium on Irrigation Problems and Crop Responses in the Southeastern States are urgently needed.[11]

A considerable time will probably elapse before a comprehensive and effective policy for using water will be established. There is a two-fold reasons for this delay. First, a comprehensive and effective policy or plan of action cannot be formulated until the obvious deficiencies in data and law on water are removed. There is considerable evidence that this deficiency is now being removed, but it will take some time to build up the data and law needed. Secondly, the public must be in general agreement on the specific objectives they wish to attain with water policy. This agreement may be difficult to attain.

It will not be difficult for a very large segment of the public to agree that the general objective of water policy should be to make water resources more useful. Likewise, it will be comparatively easy for people to agree on the type of facilities to use in converting water resources into water products. As the public acquires more knowledge about water, the engineering and economic advantages of building facilities in particular locations will become apparent. In fact, people are already becoming

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[10] Rudolph Ulrich, "Reclamation Costs: Southeast vs. West," *Journal of Farm Economics,* Vol. 35, (February 1953), pp. 62-73.

[11] *Soil Science Society of Florida, Proceedings,* Vol. 15, 1955.

aware of the need for building up-stream storage facilities to control

the flow of streams further down in the watersheds. The work that is now getting underway on controlling the upper reaches of the Kissimmee River is an example of this. However, it probably will be some time before local groups will sponsor the erection of watershed development structures rather than purely local water control facilities.

The most serious schisms in public opinion will develop over the rate at which it is desirable to use water. Some people will always want to exploit the supply of water that is currently available. Drainage facilities that make land immediately productive without making provisions for maintaining the water table at a level that will make the land productive during periods of droughts is an example of how the alterations in the hydrologic cycle can reduce its productive capacity and thus deplete a capital resource. Likewise, industrial plants that pollute streams frequently reduce the productivity of the cycle.

Others will strive to extend the usefulness of water in time in order to facilitate economic growth and provide for future generations. Planting forests and cover crops to prevent soil erosion and adjusting the rate of pumping to correspond to the recharge rate of underground reservoirs to insure a continuous supply of water are examples of managing water to accomplish ends of this kind.

It is because of inherent differences of opinion on the rate at which water resources are used that makes the subject of water conservation both important and controversial. Conservation is concerned with the when of use—in this instance, with when water is used.[12] Technically, "depletion" and "conservation" are terms used to describe changes in the intertemporal use of water. Hence, any act that redistributes the use of water into the future is conservation. Before those who design, construct, and operate facilities augmenting the productive capacity of the hydrologic cycle can manage these water supplies in accordance with the public interest, the public must provide them with some guidance as to when they want to use water. Efficient water managers can deplete the supply of water products at a particular time and in a particular place just as effectively as they can conserve it. In the absence of any specific direction as to the when water should be made useful, those who manage water supplies must establish their own conservation objectives before they make operating decisions. If they do not establish such policies deliberately, they simply allow a series of *ad hoc* management decisions to establish public conservation policy. For this reason, some statement of how people want to distribute the use of water in time is an essential requisite to the formulation of an effective water policy.

SUMMARY

When water resources are defined as being aqueous solutions containing 97 or more percent H_2O, they are available in sufficiently large quantities to permit every one to use them freely. The hydrologic cycle is a gigantic capital facility that converts water resources into water products, *i.e.*, water with specified quality chracteristics at specific times and at specific places. In the aggregate, the productive capacity of the cycle

[12] S. V. Ciriacy-Wantrup, *Resource Conservation*, University of California Press (Berkeley and Los Angeles, California, 1952).

is sufficiently large to satisfy all human wants. but the volume of geographic distribution of the products is not sufficiently uniform to maximize their utility. For centuries this has stimulated people to alter and expand the cycle in an effort to increase and regularize its productive capacity.

Both private and public organizations have been used to erect and operate the facilities that augment the productive capacity of the cycle. Private organizations are generally used when the benefits from the facilities accrue to individuals or groups that can be identified and required to pay for their use. On the other hand, when the benefits cannot be measured accurately or the beneficiary charged for the use of the facilities, they are erected and operated by public agencies.

To enable people to more accurately estimate the benefits that can accrue from new investments in capital facilities that produce water and to create a more favorable economic environment for private investments in such facilities, it will be necessary to:

1. Assemble more data on natural productive capacity of the hydorlogic cycle—more data on precipitation and on surface and ground water volumes and movements.

2. Define water rights precisely enough to permit entrepreneurs to establish their value accurately in the market place.

3. Conduct the researches needed to establish the economic value of water in different uses. especially in agricultural and recreational uses.

These three activities will help people formulate their policy with respect to water. providing they can agree on the timing of the use of water. If people want to extend the usefulness of water into the future, their objective will be to conserve it. On the other hand, if they want to increase the utility of water now. without regard for their future, they will adopt a policy of depleting the productive capacity of the cycle. In a democracy people establish public policy through their elected representatives, but before they can decide whether or not to conserve or deplete the water products available, they should know what effect the policy they adopt will have on their own economic well-being in the future and the economic well-being of future generations.

Some Aspects of the Evolution and Current Application of Water Resources Management in Florida

W. Turner Wallis *

INTRODUCTION

For more than a century of statehood, the history of Florida has illustrated the causative nature of water and the numerous and varied human adjustments to the conditions which prevailed here. Settlement and development of the peninsula have been to a large extent because of water or in spite of water, and management practices have been primarily responsive to particular local needs. For the future, the management of Florida's water resources must necessarily be more comprehensive.

Florida is as well endowed with natural water resources as any other area of equal size on the American continent. The average annual rainfall of 53 inches is almost twice the national average, and water is adequately stored on the surface in thousands of lakes and millions of acres of swamp and marsh. Additionally, hundreds of miles of streams carry fresh waters through the state, while numerous artesian springs flow from the vast limestone aquifer beneath the surface. This picture of abundance must not impart an attitude of complacency, however, because 70% of the rain that falls is returned to the atmosphere through evaporation by the hot Florida sun or transpiration from the lush plant life. In the pattern of the tropics, Florida's rainfall is highly seasonal; and during the winter periods of reduced precipitation, serious droughts often occur. In the late summer rainy season of the same year, heavy rains falling on flat, poorly drained lands can produce floods of great consequence. Thus, Florida's waters are characterized by rapid sequences of too much and too little.

HISTORICAL DEVELOPMENT

Application of the Riparian Doctrine. It was this natural problem of recurring droughts and floods which confronted the earliest settlers as they moved south into the Florida peninsula, presenting difficulties which had not previously been encountered. Early development in North Florida had produced no serious water problems. As in most of the eastern states, the riparian doctrine of English common law had been adopted in this land of plentiful water and few people. This doctrine gave the upland owner rights to the body of water he adjoined and the surface owner rights to the water in the ground beneath him. In effect, few water problems existed, and the common law proved adequate for water management at that time.

Interest in Peninsular Florida. South Florida had been little explored by the time the state was admitted to the union, but Indian wars among other things had stimulated interest in the peninsula. Much of the low, flat, slowly permeable land was covered by water, but the agricultural potential of the area was quickly recognized. The close asso-

* Central and Southern Florida Flood Control District, West Palm Beach.

ciation of water and soil in the southern part of the state has always been and remains today a dominant factor in water management practices in the area.

In 1847, only two years after the state was created, the Secretary of the U. S. Treasury was persuaded by Senator Wescott of Florida to authorize a survey of the Everglades region. Buckingham Smith, of St. Augustine, was designated for this task, and in his report he advocated extensive drainage activities in the area to reclaim large tracts of organic soil for agricultural use. His plan suggested lowering Lake Okeechobee by four feet through canals to the Caloosahatchee and St. Lucie Rivers.

Before the Smith survey could produce anything definite, the Federal government passed the responsibility for reclamation on to the states. The Swamp and Overflowed Lands Act of 1850 was especially pertinent to Florida, and through the years that followed its enactment, 20,000,000 acres of a total 35,000,000 acres of land area was conveyed to this state subject to the requirement that proceeds from the sales be used to finance reclamation activities. Actually, much of the land was not swamp or overflowed, but dry land requiring no drainage. The Board of Internal Improvement was assigned the responsibility for the administration of these lands, and the office of State Engineer and Geologist was formed to direct drainage work. The prevailing belief at the time was that these valuable lands must be divested of the covering water.

Various difficulties plagued the Board of Internal Improvement, and in 1855 this was replaced by the Trustees of the Internal Improvement Fund, composed of the governor and four cabinet members serving in an ex officio capacity. This fund incorporated several land grants including the swamp and overflowed lands and $1,000,000 already received from land sales. Regardless of the requirement to undertake reclamation, the Trustees were motivated primarily by the hope of encouraging railroads into the Florida peninsula. As a result, very little reclamation was attempted until after the Civil War.

Reclamation Efforts by Private Enterprise. In 1881, financial stringencies resulting from widespread failures of railroad development were partially relieved by the sale of 4,000,000 acres of internal improvement lands to Hamilton Disston, a Philadelphia financier, for $0.25 an acre. The plan devised by the Disston engineers was entirely sound in its concept, and during the following thirteen years produced the greatest achievements in reclamation of all private undertakings in Florida. Most of the work in this enterprise was confined to the Kissimmee Valley, although probably the single most important feature was the connecting canal between Lake Okeechobee and the Caloosahatchee River, giving the Lake an outlet to the Gulf. The Disston operations ceased in 1894, but by that time considerable acreages had been partially reclaimed for agriculture, and inland waterways had been greatly improved through the excavation of new canals. Navigation from the Town of Kissimmee to the Gulf of Mexico had been made possible, and steamships became a common sight along this watercourse. Together with the railroads which pushed progressively southward, inland navigable waterways contributed greatly to the development of south and central Florida.

Disston's activities also did much to publicize the Florida frontier. While the drainage efforts actually did little more than emphasize the

immensity of the reclamation task in the peninsula, the navigation facilities suggested areas of further development. The Federal government became interested in these possibilities, and in 1899 the U. S. Army Corps of Engineers undertook a survey of the Disston works. Other navigation improvements resulted from this survey.

State Efforts at Reclamation—the Everglades Drainage District. It had long been recognized—even before statehood was acquired—that water control was the key to development in the lower part of the state. Drainage, however, was the principal concern. Agriculture, considered to be the major economic pursuit adaptable to that area, could not be successful unless the surplus water were removed from the land. By the turn of the twentieth century, very little had been accomplished toward reclaiming even the lands of the greatest potential. Disston's venture had achieved only limited success in this respect, but demonstrated very vividly the difficulties inherent in a private undertaking of this proportion. It was evident that the state was in a better position than private concerns to reclaim its swamp and overflowed lands.

With this realization, the Legislature in 1905 authorized the Trustees of the Internal Improvement Fund to serve as a Board of Drainage Commissioners to establish drainage districts and otherwise engage in reclamation activities. The Everglades Drainage District, embracing almost 4½ million acres in south Florida, was created originally by this authority. This district expended eighteen million dollars on a plan designed primarily to control the levels of Lake Okeechobee and remove excess water from the lands to be served by a system of canals flowing southeasterly to the Atlantic Coast.

By legislative authority, numerous other independent drainage districts were established, some of which were sub-districts within the vast Everglades Drainage District. Unfortunately, most of these smaller districts as well as the Everglades Drainage District were plagued by pressure from various interests, usually land speculators who compounded the problems of the area by overselling the potential of the reclaimed lands.

Efforts by the land dealers combined with the genuine attraction of the highly productive agricultural lands contributed to settlement of the reclaimed areas. The mild winter climate combined with the fertile organic soils fostered an immediate agricultural center around the shores of Lake Okeechobee, and this region became prominent in the winter vegetable production of the country. Up until this time the threat of tropical storms—a not uncommon occurrence in South Florida—had not deterred the flurry of human activity in the area. Thus it was that when a hurricane swept through the Okeechobee vicinity in 1926, gross inadequacies were evinced in the water control and protective facilities around the Lake. A tidal wave caused by high winds topped the levees and spilled onto the developed lands in the vicinity of Moore Haven. Property damage was high, and 250 people lost their lives in the wake of the storm. In 1928, another hurricane pushed a wall of water over the levees protecting the southern and eastern shores, leaving the astounding figure of 2,400 people dead and causing damage of more than two million dollars.

Federal Interest and the Need for Flood Control. The nation was appalled by the disastrous effects of the Okeechobee floods, and the

inhabitants of south Florida had another grave lesson impressed upon them: drainage was not the single answer to successful water control. In 1929, the Legislature created the Okeechobee Flood Control District and authorized it to cooperate with the Federal Government in a plan to provide flood protection to this area, which by now had become an important factor in the economy of the state. Federal activity authorized in 1930 is significant, since all prior work by the Corps of Engineers in south Florida had been to improve navigation. Construction on this project continued through the following decade with significant achievements. The inadequate levees of the Everglades Drainage District were enlarged and expanded to protect the developed lands. Work was done on floodways, and control structures were installed to regulate the flow of water. Lake Okeechobee was made the receptacle for water removed from surrounding lands, and from the Lake the unwanted water was discharged to tidewater.

As work progressed in the Okeechobee-Everglades area, national policy regarding water control underwent a major change. Under the Flood Control Act of 1936, the Federal Government assumed the responsibility to protect its citizens from floods. In effect, however, the plan already in use was designed for that purpose. But this plan, like those which had preceded it, had a serious weakness which deprived it of complete success: it was too limited in purpose and scope. For the most part, south and central Florida comprises one large, complicated and interrelated watershed. Any plan to alter natural water conditions in a disassociated part of this watershed to serve limited purposes cannot be successful. This lack of comprehensiveness will prevent the most beneficial use of affected natural resources and tend to create or aggravate other problems.

Increasing Water Problems of Human Origin. Such was the case in south Florida during the accelerated drainage program for reclamation and flood control. As the surplus water was drained to the sea during the periods of heavy rainfall, the normally high water table was markedly lowered, leaving the area susceptible to severe droughts during the dry season which followed. The detrimental effects of drought were even more acute on the organic soils, which depended on proper water content for their very existence. Without the necessary moisture, the destruction of the exposed muck soils through oxidation and burning was rapid. In other ways, too, the farmers felt the effects of the drought. In south Florida the dry season coincides with the peak winter growing season, when the irrigation demands are highest. Nature's gift of water had by that time been drained to the sea, leaving insufficient amounts on the land and in the soil.

Florida still had no distinct water policy to govern the diverse and uncoordinated attempts at water control. Natural waters had in many cases been a deterrent to much desired development of the peninsula, and the apparently abundant supply seemed inexhaustible. As human activity increased, however, so did water problems. More and more, sound management practices were needed to combat or prevent the multiplicity of problems inherent to human habitation. These problems were by no means limited to the agricultural lands around Lake Okeechobee. Almost since the turn of the century water supply difficulties and drainage prob-

lems had attended the urban development of coastal areas. Combined effects from over-drainage and increasingly heavy withdrawals lowered the ground water level along the coast and permitted salt water to intrude into ground water supplies. New and deeper wells were moved further inland, but the salt water intrusion problem grew steadily worse.

Pollution also became a cause for concern, especially in south Florida where septic tanks proved impractical for sewage disposal because of the high water table and the saturation caused by heavy rains. Urban concentrations which grew in a poorly planned manner from land booms suffered greatly for lack of drainage and sanitary facilities. Polluted floodwaters stood for weeks on end, constantly threatening the health of the exposed people. In some cases, natural drainageways were used for the disposal of raw sewage. Increasing population and industry intensified sewerage problems, and drainage wells became popular for lack of simpler means. Through these wells, pollution spread to ground water reservoirs, contaminating municipal supplies. Stream pollution in northern Florida and saltwater pollution in bays and estuaries along the coast developed severe problems of local consequences but of widespread cause. In 1913, the state legislature enacted basic legislation to contend with the water pollution in the state. This responsibility was handed the State Board of Health, but relatively little was accomplished prior to World War II because of the size and nature of the task. Fortunately, however, pollution was recognized as a grave problem, and one that could be eliminated through effective management.

Need for Comprehensive Approach to Water Problems. It has already been stated that water control is the key to development in the Florida peninsula; it could be more properly stated that multi-purpose water control is the key to that development. This fact became increasingly apparent as successive limited purpose projects achieved incomplete results. World War II developed before this concept of multi-purpose resource programs could produce any significant undertaking. However, the accelerated pace during the war aggravated existing problems of water control and management and emphasized more strongly the drastic need for remedial measures. Economic factors made the Okeechobee muck lands even more valuable as producers of vegetables for the war effort. New lands were hurriedly drained and cultivated, and the diminished water supply was further taxed by increased demands. Florida experienced unprecedented population growth during the war years and immediately after. This influx of people resulted in rapid building programs with little provision for sewerage facilities, and high pollution incidence was a consequence. With population increases, concomitant industries and other needs, municipal water supplies were strained beyond their capacity. The need for a comprehensive water use program was acute.

Nothing accentuated the inadequacies in previous water control programs better than the flood which all but paralyzed south and central Florida in the fall of 1947. Hurricane winds and torrential rains produced a flood of great proportions, and damages were estimated at over 59,000,000 dollars. Besides thousands of acres of highly developed reclaimed agricultural lands, large urban areas along the east coast were inundated. Poorly designed or inadequate drainage facilities in many

cases proved to be worse than none at all. Flooding was obviously a natural phenomenon in this part of the state, and natural conditions had been greatly altered with no consideration for this fact. The water control problems in south Florida had reached a climax.

Under the authority of various Congressional resolutions, the Corps of Engineers was directed to conduct a survey to determine the water control needs of the area and devise a plan for that purpose. The report submitted by the District Engineer in December of 1947 emphasized the interrelation of drainage, water conservation and flood control problems and the need for a comprehensive plan to include those and all other related problems. The area being considered for improvement included four component watersheds in lower Florida: the Okeechobee-Everglades-East Coast area, the Caloosahatchee River Valley, the Kissimmee River Valley, and the Upper St. Johns River Basin. The multi-purpose, broad-scope plan was at last on paper.

THE CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT. Congressional approval was provided in the Flood Control Act of 1948, with the stipulation that the state create a single agency to discharge its share of the responsibilities. The 1949 Legislature established the Central and Southern Florida Flood Control District as a public corporation to represent the people of the area. This District, which absorbed the Okeechobee Flood Control District and acquired the responsibility for the Everglades Drainage District works, includes 15,570 square miles, embracing all or parts of seventeen Florida counties.

The Central and Southern Florida Project is truly a cooperative Federal-state-local venture. Every effort has been made to consider all local needs and desires and stay within the realm of economic feasibility. Among the multiple objectives of the project are the rapid removal of floodwaters, the storage of surplus water, the prevention of overdrainage and salt water intrusion, the protection of developed areas, the conservation of fish and wildlife, the reclamation of additional urban and agricultural lands, and some improvement of navigation. To accomplish these ambitious aims, the overall technical plan provides a closely integrated system of canals, levees, control structures and pump stations. Since the scope of this project is so broad, it is by nature a time consuming task and much of the original planning could be only tentative, pending cultural changes that are rampant in southern Florida.

One of the principal lessons learned from previous drianage projects was the absolute need to retain large quantities of surplus water in storage. For this purpose, 858,000 acres of shallow muck soil unsuited for development were planned for water conservation areas. Impounded by levees, water could be contained here during the wet periods for use during the dry season when the demands were great. Other large areas of the Everglades where the muck was deep enough to be cultivated were planned for reclamation in conjunction with the flood control undertaking. Facilities were designed in each of the major watersheds for drainage, water storage, run-off and saltwater control where needed. Pollution abatement and hyacinth eradication also were included in the plan.

Seven years of operation indicate that the present project will be infinitely more successful than its predecessors in providing remedies for the area's water control problems. Much of this success will depend

not on the primary plan alone, but on the secondary or complementary plans installed by local sub-drainage districts, by county water control authorities or by private interests. For this reason, county water conservation committees have been organized in most of the component counties, and every effort is made to secure local participation and cooperation in water control matters. Satisfactory progress has rewarded these efforts so far.

EXISTING PROGRAMS FOR WATER RESOURCE MANAGEMENT

Current Status of Water Resources. In the history of water resource management in Florida, the reclamation and flood control activities in the southern part of the state have played the dominant part. The dramatic nature of this long battle has almost over-shadowed other aspects of water resource use. Still, it is true that many administrative measures were largely unnecessary until human activity aggravated natural problems or brought new ones into being. In the western part of the United States, water management problems were incurred from the the start simply because so little water was available. In Florida, blessed with bountiful water resources, few difficulties were encountered until precipitated by population densities. Inadequate water supplies, salt water intrusion, pollution, over-drainage, flood plain encroachment and most of the other acute problems have all been primarily a product of twentieth century conditions. Relative to the remedial measures which have been instituted, these problems exist now in varying degrees of severity. Unchecked, they can only get worse as population continues to increase and new development takes place. The dynamic trends of population and economic growth witnessed today emphasize the importance of water resource management for the future.

Climate and water are undeniably two of Florida's most valuable resources. The climate is relatively free from detrimental exploitation but, as history illustrates, water is not. With past experience as a guide, however, the present and future utilization of this resource will have invaluable direction. Like most of the elements of nature, water has a dual character: a vital necessity on one hand, and a destructive menace on the other. Extant today are numerous agencies and programs designed to meet the needs generated by one or the other of the two characteristics of water. In one category are water supply, recreation, navigation, power development and the like; opposing these potentialities of water are flood control, reclamation, pollution abatement, and other such activities which are outgrowths of the negative potential of water. Both characteristics have inspired active management in Florida today.

Listed in the Hoover Commission Task Force on Water Resources and Power are twenty-five Federal agencies involved in the administration of water. Of these, at least a dozen are active or have an interest in Florida. Still, only a few of these are significant in the field of water resource development and management. Although the state of Florida has always been characterized by a high degree of local initiative in resource development, a great deal of the impetus, too, has come from the Federal level because of its superior organization and capabilities.

The Corps of Engineers. Much has already been said about the U. S. Army Corps of Engineers, and indeed this Federal arm has demonstrated an active interest in Florida for over half a century. Navigation was the original incentive for the Corps' activities, and its importance today is greater than ever. Inland waterways have declined as primary routes of transportation, but more than ever the numerous ports along Florida's coastline and the intra-coastal waterway—of which Florida has a longer segment than any other state—are increasing in economic importance. The development of these waterways and harbors is a primary occupation of the Corps of Engineers in this state. Increasing use is being made of these waterways for recreational boating, and the Corps of Engineers has been cognizant of this fact in recent planning.

Probably the most significant of all the Corps activities is flood control, which has been a responsibility of the Federal Government since the disasters in the Ohio Valley precipitated the 1936 Flood Control Act. Large, multiple-use projects like the Jim Woodruff Dam on the Apalachicola River are one means of attacking flood problems, but conditions in Florida generally do not lend themselves to this type of solution. In this state, the most significant flood control work of the Corps is in the cooperative Central and Southern Florida Project already described.

In recent years the Corps of Engineers has inaugurated a small projects program designed to complement its program of "downstream" works. In its present form, this program is authorized up to $10,000,000 annually for use on small projects, with a limit of $400,000 on any one. Projects under this program do not require Congressional approval, but only the administrative endorsement of the Chief of Engineers, and they may not be an element of a Congressionally authorized project. The projects must be complete in themselves, and are prevented by area limits from being concentrated in one locality. Because of the immediate or emergency nature of most of these small projects, they generally require less local participation. Local interests are required to furnish easements and rights-of-way, hold and save the United States free from damages incurred in construction, and maintain the completed project. Although only in its incipient stages, this program has numerous projects under investigation throughout the country, and its application to needs in Florida will prove highly beneficial.

The Soil Conservation Service. Because the problems of water management are so closely related to those of soil management, the Department of Agriculture is actively engaged in water conservation in Florida. These activities are carried on primarily through the programs of the Soil Conservation Service, the Agricultural Conservation Program and the Farmers Home Administration. The Soil Conservation Service bears the brunt of most of the Department's responsibilities. Since its creation in 1935, this agency has provided invaluable services to farmers and landowners in helping them plan and utilize their water and soil resources in the most beneficial manner. This task has been greatly facilitated by the organization of soil conservation districts, of which there are fifty-nine in Florida at present, generally coinciding with county boundaries. Through these districts, a high degree of cooperation is obtained, and technical guidance is furnished from the Service. Over nine million acres in this state have been planned under this program,

and thousands of on-the-land water control structures have been installed. The possibilities of this program are just being realized, and even greater success is indicated for the future.

As far back as the 1936 Flood Control Act, the Department of Agriculture was assigned the responsibility for flood prevention in connection with other watershed activities, but no effective program was implemented. With the passage of Public Law 566 by the 83rd Congress, a program of "upstream" works for watershed protection and flood prevention was authorized, and the Department of Agriculture assigned responsibility for this program to the Soil Conservation Service. This small watershed Act, as amended by Public Law 1018, 84th Congress, is designed to make possible water and soil conservation along with flood protection on a cooperative basis within watersheds no larger than 250,000 acres. This program places the initiative and a major part of the responsibility for execution, operation and maintenance on local interests, who must organize a watershed authority, acquire the approval of the state and make application for Federal assistance. Local interests also must acquire all necessary water rights as prescribed by state law, obtain agreements from at least fifty percent of the landowners in a drainage area to carry out recommended soil conservation measures, assume a proportionate share of construction costs, acquire rights-of-way and other necessary lands, and assume responsibility for operation and maintenance of completed works.

These numerous stipulations and the many required reviews result in considerable delay before a project is approved, but by and large the provisions of Public Law 566, as amended, are favorable to local interests in filling a need in the National flood control program and in enabling them to undertake projects they could not support alone. Projects in this case need only administrative approval of the Secretary of Agriculture rather than separate Congressional authorization, and subwatersheds when they are component parts of a larger watershed may be planned together under this Act. Although the possibilities under this small watershed program are legion, little has been done in Florida to date. Seven applications have been made, covering over a thousand square miles, but only one application has been approved.

The U. S. Public Health Service Anti-Pollution Program. Although the U. S. Public Health Service has many responsibilities dealing with public water supply, its primary contribution to the management of water resources is in pollution control. Insofar as the Florida State Board of Health is unable, the Public Health Service provides engineering and other assistance directly to the state as needed. Pollution is recognized as a menace to public welfare as well as to wildlife and other resources, and the duties of the Public Health Service in combating water pollution are well defined in the Blatnik Bill, which was enacted as Public Law 660, 84th Congress. The provisions of this water pollution control Act gives states and communities a good instrument for cooperative anti-pollution campaigns. Other than financial help, the Federal government will provide technical and other services through the Public Health Service, which is directed to develop comprehensive programs for controlling pollution in interstate waters, encourage water conservation measures, encourage cooperative activities and appropriate legislation within

the state for water pollution control, conduct an information program and support research projects pertaining to water pollution control, initiate appropriate enforcement action, and provide financial assistance to state agencies for the expansion of their programs. This Act stresses the supplementary nature of the funds available through it, and it is not to be construed that a very definite state responsibility is being totally assumed by the Federal Government.

State Programs. Of the many active state programs of water management and administration, some augment the programs of the Federal Government and some have entirely different functions at various levels. Generally, the government of the state of Florida administers the program directly through an appropriate agency or provides the authority for administration at a lower level. The fields of water resource management often overlap, as do the activities of similar agencies at different levels, but a creditably high degree of cooperation among the various interests has succeeded in provided Florida with a well-balanced water resources program.

Among the more efficient water resource programs in the state are those instituted through state authority at a local district or watershed level. These organizations can develop plans of improvement designed to meet local needs, and are generally effective in maintaining local support. The advisability of solving water problems at the lowest practicable level is evidenced in national policy by the small project programs already discussed. Some of the state authorized local programs active in Florida are described in the following paragraphs.

Local Water Control Authorities. In 1945, Florida law authorized the Dade County Commission to create water conservation districts, and the entire county was established as the Dade County Water Conservation District. Financed by a half mill ad valorem tax, this district has pursued an aggressive program of construction, improvement and maintenance of water control works. The Water Control Division was responsible for the minimum land elevation map used by the county to regulate urban development in areas susceptible to flooding. Since the inception of the Central and Southern Florida Project, adjustment has been made to integrate the Dade County plan into the more comprehensive one.

Also in 1945, the Legislature passed a Special Act creating a Fresh Water Conservation Board for Pinellas County, with the Board being comprised of the County Commissioners in an ex officio status. Powers of water regulation, taxation and other operating requirements were assigned to the Board. Following the plan and priority developed by the Soil Conservation Service, Pinellas County has also made considerable progress toward the solution of local water problems.

Another type of local water control group is illustrated by the Oklawaha Basin Recreation and Water Conservation and Control Authority. This project was authorized as a political subdivision of the state by special act of the Legislature in 1953. It is completely local, being contained in Lake County and financed by a one mill annual levy on real estate. Water conservation through the regulation of the important lakes in the area is the primary feature of this project.

The Water Resources Study Commission. Florida is a fortunate state in having the benefit of an extensive and detailed evaluation of its present water situation and the prospects for the future. At the recommendation of the temporary advisory committee previously appointed by the Governor, the 1955 Legislature created the Water Resources Study Commission. This group was charged with the responsibility of conducting an exhaustive survey of the state's water resources and making recommendations to the 1957 Legislature for the protection and beneficial use of those resources. Informal county committees were appointed, and meetings were held by each to determine the nature and extent of water problems at the lowest possible level. Concurrently, specially appointed committees of well qualified individuals were engaged in detailed studies of water availability, water uses, water law, and other such aspects of this resource. As the information was completed, conclusions were drawn and recommendations for improvements were formulated. Public hearings at various localities around the state brought these conclusions and recommendations to the attention of the people whom they concerned.

Much of the success of water management programs in the future will depend on the water policy or policies adopted for application throughout the nation and the state. In recent years, three very significant efforts have been made at the national level toward the ascertainment of such a policy: the Presidential Advisory Committee on Water Resources Policy, the Second Hoover Commission Task Force on Water Resources and Power, and the Jones Subcommittee of the House Committee on Public Works. At the state level, the Water Resources Study Commission represents an effort toward similar ends. Dating back to the institution of the riparian doctrine, water utilization in Florida has adhered to no uniform system. Many complications have developed which are detrimental both to the resource and to the interests of the user. There exists a definite need for a sound policy to give direction to future water management and insure the maximum beneficial use.

Creation of the Water Resources Study Commission indicated a cognizance of this need by state legislators. The institution of this study program was very timely, and the appointed Commission and the countless cooperators have responded with a highly creditable report. It is an obvious fact that before any remedial or anticipatory action can be taken, the existing situation must be analyzed and evaluated. Florida has made commendable progress in this respect.

PUBLIC RESPONSIBILITY FOR FUTURE DIRECTION

The abundance of Florida's water resources has already been expressed. It remains for the people who will always be dependent on these resources to provide them the best of care. Even a brief description of the water management programs illustrates the recognition of and the response to water conservation needs in this state. But it also points out inadequacies. Possibly the greatest of these lacks is at the fourth level of water conservation responsibility—the private individual. The Federal government, the state, and the local cooperatives are aware of the problems with which they must contend and are exercising the limit of their authority to accomplish the tasks assigned them. The individual, however, has an

equally important function, and must not ignore that responsibility through apathy or complacency.

Public education of water conservation problems and needs has always been an overwhelming job. Local situations often call these problems strikingly to the public's attention, only to be assuaged with the passage of time. Florida's rapidly growing population and drastically changing economy are likely to produce more serious consequences from water problems in the future, and this eventually must be anticipated before irremediable situations develop. Many possibilities exist whereby government programs can be used for the solution of local problems. Pollution is certain to become more serious with expanding industry and denser population unless some provision is made. Wider application of the Blatnik anti-pollution act will prevent pollution problems from developing in many cases. Similar aid may be obtained through local initiative from the Soil Conservation Service small watersheds program or from the Corps of Engineers under its small projects authority. It is an individual responsibility in an area of need to take advantage of the possibilities of public assistance. Of course, watershed organizations or drainage districts are necessary to receive such aid, but these organizations are composed of individuals with common needs and are brought into being through the efforts of individuals, either singly or cooperatively.

CONCLUSION

Water has always been an important part of the natural heritage of the people of Florida. Through years of heedless exploitation, serious cultural problems were added to the already existing natural problems. Partly due to the mistakes that were made, Florida's water resources are now justly appreciated at most levels, and numerous programs for wise and beneficial water use have been instituted. The effectiveness of many of these programs has been demonstrated: others must yet be proved. But much of the significance in the number and variety of programs is in the awareness and interest at governmental levels. Only the assurance of public support is a questionable factor; and that responsibility belongs to the people of Florida.

FINDINGS AND RECOMMENDATIONS OF THE FLORIDA WATER RESOURCES STUDY COMMISSION

Wednesday, November 28—7:30 P.M.

A Report on the Florida Water Resources Study Commission

David B. Smith *

Florida, like most other eastern states, has long used its water resources without the guidance of a state policy. Scattered statutory law and court decisions have been the only landmarks in determining the rights to use water, and many gaps have been found to exist in the state's water law. However, the severe drought of the past two years pointed up the need for state-level interest in the proper management of this important resource, and the 1955 Florida Legislature established a policy designed to fit the needs of the state. It is repeated here in full.

"(a) Waters in the state are a natural resource.

"(b) The ownership, control of development and use of waters for all beneficial purposes is within the jurisdiction of the state which in the exercise of its powers may establish measures to effectuate the proper and comprehensive utilization and protection of the waters.

"(c) The changing wants and constantly increasing needs of the people of the state may require the water resources of the state to be put to beneficial uses to the extent of which they are most reasonably capable and therefore the waste and unreasonable use of water should be prevented and the conservation of water should be accomplished.

"(d) The public welfare and interest of the people of the state require the proper development, wise use, conservation and protection of water resources together with the protection of land resources affected thereby.

"(e) The state should make a careful and comprehensive study before enacting any legislation affecting the matters heretofore stated in this Act."

At the same time the legislature recognized the need for an over-all evaluation of the state's water resources, and the Florida Water Resources Study Commission was created for this purpose. The Commission was instructed to conduct a study into the matter of implementing the state's water policy by legislation and to report its findings to the 1957 legislature.

In outlining its program the Commission felt that a survey was essential to determine the problems which local users were experiencing day

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by day in attempting to put water to beneficial use. The members felt that it would be desirable to have problem inventories made in each county of the state, and early in 1956 the Commission formed a water problems committee in each county in order to obtain this information. Committee chairmen were selected in each county, and they in turn determined a time and a place for each county committee meeting, and issued invitations to everyone in the county to attend and participate in the committee operation.

More than 130 chairmen gave freely of their time in organizing and conducting the county studies, often with considerable sacrifice of time and money. In all, over 1,300 people attended and participated in the local water problems inventories. In most of the counties, those active on the committee represented most or all major fields of water use. They included representatives of several state organizations, and state and federal agencies concerned with wateruse, businessmen, farmers, lawyers, industrialists, professional men, and others. By mid-July, the county inventories had been completed and reports were received from every county in the state. All recorded problems that have or may have legal, administrative, or economic implications were then extracted from the reports and summarized. A similar but more limited problem inventory completed in 1954 by the Florida Association of Soil Conservation District Supervisors was also studied by the Commission. The county water committee reports represent what is thought to be a typical cross section of the state's water problems, but no assumption is made that the reports constitute a full and final catalog of such problems in Florida.

It is common knowledge that in Florida we have been plagued from our earliest history by problems arising from excess water. At first, problems of flooding were most common. Later, as the economy of the state expanded, problems of removing excess water—drainage—from agricultural and other lands and as a health measure assumed greater importance. Problems of this type will continue in the future in some localities, as is indicated by both the 1954 and 1956 studies; although considerable progress has been made in Florida in combating flood problems and providing needed drainage facilities. Problems arising from attempts to put water to beneficial use were relatively unimportant a few years ago, but are now becoming increasingly more common. Both studies emphasize this fact, but it is strikingly revealed in the recent study. In the 1956 inventories problems of use were reported by many counties. The inventories clearly point up the fact that problems of use are likely to become increasingly prevalent in future years, especially in certain communities. The problems summary also indicates that problems of development, use, conservation and protection of our water resources vary in combination from area to area in the state.

A second major Commission operation was that of organizing a committee on Water Law. This committee was organized under the auspices of the Florida Bar for the purpose of undertaking a study of the existing law of Florida as it pertains to water resources. This work was accomplished by a thorough investigation of the case and statute law of Florida and the federal law which affects Florida's water resources. The committee compared the results of the legal study with the need indicated by the Commission's inventory of local water problems in order to de-

termine how well the existing law is geared to meet these problems and needs and what gaps and defects exist in the present legal picture.

A third operation of the Commission was that of investigating and reporting on the water resources programs currently in operation. This study furnished an outline of the authority and the program of operation of the various local, state and federal agencies operating in the water resources field in Florida. The results of this phase of the Commission's operations reveal those water resources which are subject to management by an existing agency as well as the areas in which no management is practiced.

Another Commission activity of considerable importance was that of establishing several state-wide fact-finding committees. These were committees on Present and Future Water Use, Quality of Water, Climatology and Meteorology, Surface Water, Ground Water, Land Use, Beach and Shore Erosion, and Water Pollution. As the committee names imply, each committee was asked for data on a state-wide basis from the technical and engineering viewpoint, so as to obtain an integrated picture of the complex water resources story in the state. Membership of the committees was obtained by invitation to all known organizations and agencies in the state whose interests lie in the respective fields of committee work. Forty-four groups responded to the invitations by designating one or more individuals to represent them on the committees. Much of the following data were obtained as a result of the various committee operations.

The most striking aspect revealed by the Commission's study of Florida's water resources picture is the quantitative and qualitative variations. Although Florida is a water-rich state, there is ample evidence to show that most of the state's fresh water supply could be put to beneficial use with uniform temporal and spacial distribution. However, the supply is not obtained at a uniform rate, and it is this factor of variability that necessitates water management operations—to dispose of temporary excess waters that cannot be conserved and to conserve water during periods of temporary excess for use in times of drought.

All of Florida's surface and ground waters originate with rainfall on the state and on western Georgia and southeastern Alabama. Throughout the area precipitation conditions are quite varied both in annual amounts and seasonal distribution. Annual averages range from as high as 66 inches to as low as 45 inches, while extreme values have exceeded 100 inches per year and have been less than 29 inches per year. Seasonal distribution further accentuates the uneven rate of supply. About two-thirds of the annual rainfall occurs in a 4-month period, which in some areas does not coincide with the time of greatest need. A majority of the supply is consumed by evapotranspiration. The rate of this use has been measured at 0.15 inches per day, a rate that exceeds the average daily rainfall in most areas. Under natural conditions this rate is not maintained continuously, since optimum water content is not always present in the soil. Yet for agricultural areas this high water transport must be maintained to obtain top crop yields, and water control must be practiced to supply that amount which precipitation fails to provide. In 1956 about 16,000 water control systems were operated in the state supplying almost 750,000 acres of productive farm land with irrigation water.

About 23 per cent of the water received as rain moves to the ocean via surface channels. In its transit the surface water forms 12 large river basins and innumerable smaller ones and is often temporarily stored in upwards of 30,000 lakes. This water averages some 40 billion gallons daily but the actual flow reflects the rate of rainfall with some time lag. The ratio of minimum to average to maximum flows of the state's streams is 1:5:120, thus illustrating the temporal extremes of surface water distribution. The special distribution is also poor. For example, more than 88 per cent of the average surface runoff is found in only five rivers—the Apalachicola, the Choctawhatchee, the Escambia, the Suwannee and the St. Johns. Spring flow, an indication of the quantity in ground storage, also reflects rainfall variations. In 1956 the gross minimum flow from nine large springs showed a reduction of 36 per cent below average flow. The quantity of ground water is large, however, and there has probably been no general permanent lowering of the state's water tables or piezometric pressures. The most serious ground water problem is salt water intrusion resulting from localized heavy withdrawals by municipalities and industries in combination with overdrainage of surface areas whereby the recharge of the underground aquifers is decreased. In addition to quality deterioration from salt water intrusion, municipal and industrial pollution have decreased the quantity of usable ground as well as surface water in some trouble spots. An aggressive and sound pollution abatement program, administered by the state board of health, has done much to prevent the water pollution problem from becoming general, but the continued growth of population and industry in the state will necessitate an enlargement of the program to keep the problem under control.

Another factor that points up the need for water management in the state is the concentration of water usage. Most of the requirements must be met in relatively small areas of intensive agricultural efforts, high population concentrations, or heavy industrial consumption. An inventory of present and future water use by major category shows the following:

	1956 Water Use	*1970 Water Use*
Irrigation	1,182	2,200
Industrial	2,227	3,420
Municipal	494	790

(Note: All values are in million gallons daily.)

The fourth major water user is the recreational category, but quantitative valuations of the amount of water used for recreation purposes are not possible. Instead, this use was measured in terms of dollars expended for boating, fishing and hunting in the state's fresh water areas. It was estimated that $381,000,000 was spent in 1955 for recreational use of the state's fresh water resources, thus showing the importance of this type of beneficial water use to the state's economy.

At the conclusion of its fact-finding operations and with the help of suggestions received at public hearings in Miami, West Palm Beach, Ft. Myers, Tampa, Pensacola, Tallahassee, Jacksonville, and Orlando, the Commission formulated its recommendations to the 1957 Legislature. They are:

1. That a comprehensive water law be established in Florida.

2. That the law preserve insofar as possible the existing rights of water users in Florida as developed by our present statutes and case law.

3. That in the law a set of legal definitions be included so as to clarify existing water law and the rights of our people thereunder.

4. That a department be established under the state board of conservation to administer the comprehensive water law and to assure the fullest utilization of the state's water resources by research, planning and implementation. Further, that the board be instructed to make periodic recommendations to the legislature for suitable programs and legislation based on the board's findings.

5. That the board be authorized to exercise regulatory powers over the use of the state's water resources only after full public hearings are held and a determination made that such regulation is necessary in the general welfare. Further, that such regulatory powers include the following functions:

a. To authorize the capture, storage and use of waters, including floodwaters, in excess of existing reasonable uses; and to authorize the diversion of such waters beyond riparian or overlying land; and

b. To establish reasonable rules for conservation of water in regions where diversion of surface or underground waters exceeds or threatens to exceed the natural replenishment of such waters or to render them unfit for use by reason of salt water intrusion or other causes.

6. That provision be made for appeals to the courts of Florida from decisions of the board.

7. That a program be established by the board to provide the public with useful and current information on the activities and findings of the board and its cooperating agencies.

8. That the board be authorized to cooperate with federal, state and local agencies and with water use organizations in Florida, when such cooperation will contribute to the realization of the over-all water policy developed and administered by the board.

9. That the board be authorized to require permits for, and establish conditions with respect to, all artificial weather modification attempts within the state.

10. That a state agency be instructed by the legislature to investigate the beach and shore erosion problem in Florida and to make recommendations concerning the desirability of establishing comprehensive beach and shore erosion protection laws.

11. That funds be made available to complete such mapping in Florida as is necessary to determine the major hydrologic areas of the state.

The Commission believes that legislative acceptance and implementation of these recommendations would clarify the legal picture of water rights in Florida and would form a sound foundation upon which a reasonable and proper water management program for the state can be constructed.

SYMPOSIUM: SOIL MICROBIOLOGY

Thursday, November 29—8:30 A.M.

CHARLES F. ENO, Moderator*

Microorganisms Isolated from Feeder Roots of Citrus Seedlings Affected by Spreading Decline

WILLIAM A. FEDER, JULIUS FELDMESSER, and
CHARLES H. WALKINSHAW, JR.**

Recently, considerable experimental evidence has been uncovered to support the suggestion that plant parasitic nematodes affect the incidence and severity of various fungal and bacterial diseases. Various nematode-fungus or -bacterial complexes have been uncovered in these studies. Early work in England and the Netherlands indicated that *Ditylenchus dipsaci*, the bulb and stem nematode, and *Fusarium* were intimately involved in the rotting of narcissus bulbs, but no attempt was made to work out any possible interaction between the two pathogens(14). Several workers have indicated that the severity of *Fusarium* infections in cotton, wheat, and tomato is affected by the presence of root-knot nematodes(1,2,3). It has also been demonstrated that the degree of resistance exhibited by varieties of tobacco to Granville wilt and black-shank may be altered significantly when these varieties are exposed to nematode damage(5,7). Stewart and Schindler have shown that the expression of bacterial wilt in carnations is altered markedly in the presence of a number of plant parasitic nematodes(10). In addition to the direct effects of nematodes acting as mechanical wounding agents, of which the above studies may serve as examples, nematodes may also affect the incidence of disease or its degree of expression in other, indirect, ways. For example, these same authors have shown that the incidence of Fusarium wilt in carnations is retarded by the destruction of the fungus by the feeding of the bulb and stem nematode(8). No effect of root-knot nematode infection on the incidence of Fusarium rot of gladiolus corms was observed by McClellan and Christie, indicating that nematodes and fungi may be present in the same soil and may attack susceptible hosts without any apparent interaction between the pathogens(6). While the incidence of disease was not influenced by the presence of nematodes its severity was in some cases much greater when nematodes and fungi were acting together, though no interdependence between the activity of the fungus and that of the nematode was demonstrable(2,4). Though spreading decline of citrus is known to be caused by the burrowing nematode, *Radopholus similis* (Cobb) Thorne(12), a number of fungus species have been found associated with the feeder roots of citrus trees affected with this condition

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(9,11,13). Studies were, therefore, undertaken to discover which fungi and bacteria were regularly associated with citrus roots affected with spreading decline, exactly which portion or portions of these roots were invaded by these microorganisms, and what role, if any, these microorganisms played in a nematode-fungal or bacterial complex. The present paper is a report on isolation techniques used, organisms isolated, and the tissues from which they were isolated.

MATERIAL AND METHODS

All studies were made on burrowing-nematode-infected roots of Duncan grapefruit seedlings grown in naturally infested grove soil in pots, crocks, or soil tank. The plants ranged in age from 3 to 15 months. All isolations were made from roots showing nematode lesions. Root pieces from which isolations were made ranged from 1 mm. to 15 mm. in diameter. These were thoroughly washed in tap water to remove all adhering soil particles, surface-sterilized by one of a number of methods, and then plated out on a number of different media.

Mercuric chloride (0.1%) for 2 minutes, calcium hypochlorite (5% active chlorine) for 15 minutes, or running tap water for 1 hour was used to surface-sterilize the root pieces. Some of the pieces were sterilized first and then split with a sterile blade and plated. Others were split first and then sterilized and plated. In a third group, the stele was separated from the cortical region of the root and the two regions were handled separately, the sterilizing agents mentioned previously were used. In order to stimulate selectively the growth of fungi or bacteria, we used a number of different media. These included potato-dextrose agar, potato-dextrose agar acidified with lactic acid, potato-dextrose-peptone agar, yeast-dextrose agar, nutrient-dextrose agar, cornmeal agar, malt agar, and a citrus-root-dextrose agar. Cultures were held at room temperature and in an incubator at 28° C. Wet sponges were kept in the incubator to insure sufficient hunmidity in the dishes and culture flasks. No single spore isolates were made.

RESULTS

About 1900 root pieces were cultured; 650 of these yielded no fungi or bacteria. About 96 percent of the fungi isolated were in the genus *Fusarium*. These fusaria have not yet been identified as to species. *Fusarium* spp. were readily isolated from the phloem and cortical region of the root and were consistently found in the callus tissue immediately surrounding the nematode lesions on the roots. *Fusarium* spp. were readily isolated from surface-sterilized root pieces which had been cut aseptically before plating. Some root pieces were carefully stripped of all outer tissues, including the cambial layer, and the woody xylem cylinder was surface-sterilized, cut longitudinally or transversely, and plated. These tissues also yielded *Fusarium* spp., indicating that the mycelium was present in the woody tissues of the vascular system as well as in the cortical and phloem areas.

A number of other fungi, including *Trichoderma*, *Penicillium*, *Mucor*, and *Rhizoctonia*, were associated with the lesions but were never recovered from the xylem tissues. In addition, two bacterial forms were isolated

consistently from the lesions, but only occasionally from the xylem. One was a gram-positive and the other a gram-negative motile rod.

Radopholus similis individuals obtained from these lesions were cleaned in mercuric chloride (0.1%) for 5 minutes, rinsed in sterile distilled water, and placed on the various agar media. Some were left intact and others cut with a sterile blade. Nematodes cleaned and handled as described were found to be internally and externally free of fungi or bacteria.

Burrowing nematodes have been found in the stele, as well as in the cortical area, of infected roots.[1] The presence of *Fusarium* in the xylem area suggests that this microorganism, already present as a soil inhabitant, either grew into the infection courts made by the nematodes or was carried in on the surface of the nematodes. The presence of *Fusarium* in the xylem and bacteria in the cortical regions of these nematode-infested seedlings suggests that these organisms may be involved in a complex with the burrowing nematode, and a further study of their role in such a complex seems indicated.

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[1] Personal communication from Dr. E. P. DuCharme.

Microbiological Response in Soil Fumigated with Crag Mylone as Affected by Rates, Application Methods and Planting Dates

A. J. Overman and D. S. Burgis *

It is not sufficient in soil fumigation research to determine whether a chemical has nematocidal, fungicidal or herbicidal properties. When the fact has been established, then must follow the experimentation which will answer the following questions:

1. What rate of application will be most efficient on the soil types involved?
2. What conditions should exist in the soil to obtain optimum results?
3. How should the material be applied economically?
4. For how long does the soil contain chemical components toxic to plant growth?

In various trials since 1952 at the Gulf Coast Experiment Station, Crag Mylone (3,5-Dimethyltetrahydro-1,3,5,2 H-thiadiazine-2-thione) has proven an effective control for nematodes, soil borne fungi, and weeds(1). Used at rates of 25, 50 and 100 pounds per acre worked into the top 2 inches of soil and drenched with water Crag Mylone controlled nematodes in raised seedbeds even at the 25 pounds per acre rate(2).

In work with gladiolus(5) in the field 50, 75, and 100 pounds per acre applied by three different methods indicated that a rototilling procedure was much better than simply drenching the material on the soil surface before or after planting. All treatments gave effective nematode control in this Leon fine sand, but none of the three rates was apparently adequate for soil fungi control. Nitrification was not significantly altered. Examination of plant roots one month after planting showed that Crag Mylone at 100 pounds per acre worked into the soil with potatoes forks and overhead irrigated immediately gave a high degree of root-knot control. Where 100 and 200 pounds of the material per acre were broadcast and rototilled to approximately a 7 inch depth, nematode control was not consistent at the lower level but effective at the high rate. Reduction of soil fungi populations occurred with both treatments, but nine weeks after treatment only dilution plate counts made from soil treated with 200 pounds per acre showed significantly fewer fungi than those isolated from untreated soil. Actinomycete populations were reduced 30 percent by the lower rate of Crag Mylone and 50 percent by the higher rate. The nitrification process was decreased by both rates for two weeks following treatment. In tests where the material was drenched on the seedbed surface at 200 pounds per acre rates, results were comparable to the application with rototilling(4).

From all these data it became increasingly evident that as a general preplanting soil treatment for the partial sterilization of the soil, the

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optimum per acre rate for the sandy soils of the west coast area of Florida is between 100 and 200 pounds. Also, for large areas rototilling showed promise as a practical means of incorporating the dry material into the soil.

Material and Methods: In the spring of 1956, an experiment was designed on a Leon fine sand with an average pH of 6.6 to establish the rate of Crag Mylone most effective under conditions created by rototilling the material into the soil. Three rates of application were used: 100, 150, and 200 pounds per acre. To determine whether compaction of the rototilled soil would increase the efficiency of treatment, half the plots were rolled. Moisture content of the soil at time of treating was 14 percent and within 24 hours one-half inch of water was applied through the overhead irrigation system. Interval of time between treating and planting of the crop was included as a factor: sections of each treatment were seeded 1, 3, 6, 8 and 10 days after application of the Crag Mylone. Carrots and peppers were used as indicator crops: carrots being sensitive to rootknot nematodes but tolerant to the chemical whereas peppers are sensitive to the material but rather tolerant of root-knot.

Results: Plant response indicated that no significant phytotoxic components of Crag Mylone remained in the soil 6 days after treatment. Germination of carrots seeded 1 day after treatment and peppers seeded 1 and 3 days after treatment was significantly reduced. Compacting of the soil surface following rototilling produced no apparent effect on efficiency of the treatments(3). Dilution plate counts (Table 1) made from plot soils before and 1, 4, 8, and 13 weeks after treatment showed that Crag Mylone significantly reduced populations of soil fungi. There was no difference in initial effectiveness of the rates used as measured 1 week after treatment. However, a difference was present at subsequent samplings. Increase in numbers of fungi in the 100 and 150 pounds per acre treated soil were greater than that which occurred in the 200 pounds per acre treatments, so that the high rate gave the longest and most thorough fungicidal control.

TABLE 1.—Relative Populations of Soil Fungi in Sandy Soil Treated with Crag Mylone (Number of Colonies $\times 10^{-3}$/g of Dry Soil from Plots Treated as Indicated).

Time Lapse After Treatment	Feb. 28 0	March 13 1 Week	April 2 4 Weeks	May 1 8 Weeks	June 4 13 Weeks	Sum of Samplings
Application Rates (lbs./acre)						
None	157	211	183	217	247	1015
100	119	54	93	134	129	529
150	127	33	76	105	114	455
200	174	22	35	51	48	330
L.S.D. (.05)	34					122

Nitrification studies showed that the concentrations of Crag Mylone which were rototilled into the soil had no effect on the power of the soil organisms to oxidize ammonium-nitrogen to nitrate-nitrogen. This par-

ticular season's data are at variance with data obtained in the past where 100 and 200 pounds per acre rototilled or drenched into the soil depressed nitrification for 2 weeks (4,5).

Nematode control was adequate with all three rates of the chemical rototilled to a depth of 7 inches. The seedbed area was infested with a heavy population of *Hoplolaimus* spp. and *Meloidogyne* spp. A moderate infestation of *Belonolaimus gracilis* and *Criconemoides* spp. was uniformly distributed through the field. Extractions of soil by the modified Baermann technique from the seeded areas one and four weeks following rototilling showed that all rates were efficient in decreasing the number of nematodes present (Table 2).

TABLE 2.—COMPARATIVE POPULATIONS OF NEMATODES * FROM SOIL TREATED WITH CRAG MYLONE.**

Time Lapse After Treatment	Feb. 28 0	March 13 1 Week	April 2 4 Weeks
Application Rates (lbs./acre)			
None	180	900	344
100	276	6	4
150	223	0	0
200	163	4	0
L.S.D. (.05)	211		

* Counts included the following: *Hoplolaimus* spp., *Belonolaimus gracilis*, *Criconemoides* spp., and larvae of *Meloidogyne* spp.

** Extracted by the modified Baermann technique from 150 cc fresh soil.

Root-knot control was measured at time of thinning carrots (Table 3). The two-month-old plants were rated for severity of galling on feeder roots and malformation of the carrot attributed to invasion of the *Meloidogyne* spp. of nematode. Ratings ranged from zero for plants showing no infestation to 5 for plants showing severe damage. All treatments reduced the amount of root-knot galling on the plants.

TABLE 3.—ROOT-KNOT INDICES OF CARROTS GROWN IN SOIL TREATED WITH CRAG MYLONE.*

Application Rates (lbs./A)	At Thinning	At Harvest
None	4.20	4.86
100	1.26	1.44
150	1.79	1.44
200	2.13	.36
L.S.D. (.05)	1.47	1.20

* Plants from seed sown 10 days after soil treatment.
Rating (0 = none, 5 = severe).

Root-knot indices taken at harvest of the carrots were a reflection of the data taken at thinning. There was a significant increase in length of the carrots grown in soil treated with 150 and 200 pounds per acre

of Crag Mylone. The presence of fewer malformed carrots indicated that plants grown at the higher rates of treatment may have been protected from nematode invasion longer than those grown in other plots.

These data indicate that Crag Mylone rototilled into a 7-inch depth of a sandy soil under conditions which prevailed at the time of this experiment is an effective fungicide when applied at the rate of 200 pounds per acre. All rates used gave adequate control of nematodes.

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Compost as a Means of Garbage Disposal

M. S. Anderson *

Garbage is an important waste product of every home and of other institutions where food is prepared for human consumption. It consists of a variety of organic materials, including fruit and vegetable trimmings from many kinds of plants, fragments of lean and fat meat, and substantial quantities of bones and other animal parts. The various materials present in garbage consist essentially of the major food classes known as carbohydrates, proteins, fats and minerals; fibers also are present. The water content is usually high—70 to 80 percent. Such material undergoes spoilage rather rapidly under favorable temperature conditions. Garbage is usually of unpleasant odor, particularly when animal products are included.

THE DISPOSAL PROBLEM

The Bureau of the Census reports that about 64 percent of our population live in cities and smaller communities classed as urban. This means that about 100 million people in the United States produce garbage with each person contributing a daily average of about one half-pound of garbage. Thus, about 29 thousand tons per day is urban production; annual production is about 10 million tons. On a dry basis this should mean about 2.5 million tons. Garbage contains material of possible value for agriculture and, to a limited extent, for industry because of its crude-fat content and methane-gas potential. Since garbage must be disposed of in some manner, a challenge is offered to soil and plant scientists and to municipal officials to find economic methods of disposal. Conversion into composts and subsequent utilization for soil improvement is one of the procedures considered.

The present report includes a discussion of composting processes and a description of garbage composts collected through varied agencies. Laboratory data are presented to aid in the characterization of materials with respect to their possible usefulness for soil improvement. Some consideration is given to economic factors involved in the production and use of garbage composts.

METHODS OF DISPOSAL

For many years most of the urban garbage of the United States has been collected for disposal (15).[1] In Washington, D. C., the cost of garbage collection is about 11 dollars per ton delivered at a central transfer station. Some additional cost is also involved. In other cities there is a cost of 4 to 8 dollars per ton for disposal after delivery to a central station. Separation of garbage from bottles, cans, and other rubbish,

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[1] Numbers in parentheses refer to Literature Cited.

at homes and in food-serving institutions is usually desirable. Such is often, but not always, current practice. It is possible also to make separations at the point of disposition.

Some 30 years ago large quantities of city garbage were converted to a tankage product containing about 2 to 3.5 percent nitrogen. It was moderately useful as a low-grade nitrogenous fertilizer or soil amendment. The fats extracted also were marketed advantageously at that time. Changed economic conditions have now rendered this form of processing essentially obsolete.

The so-called sanitary land fill is widely used today as a means of garbage disposal. Low-value land, suitably located with respect to a city, is an essential factor. Disposal of garbage in this way may lead, however, to pollution of underground water supplies.

Incineration is sanitary but expensive. Furthermore, the presence of an incineration plant is usually not desirable in a residential neighborhood; residents also often object to excessive passage of garbage-collection trucks along their streets. Some years ago coastal cities often transported their garbage out to sea for disposal. Contamination of shore areas led to abandonment of this practice in most places.

Modern homes frequently have garbage grinding units that are connected with the sewer system. Relatively large quantities of water are usually needed to flush the waste materials through the system. Several cities collect garbage and from a central station pass it into the sewer for subsequent digestion. In some communities the feeding of cooked garbage to hogs is a satisfactory means of disposal from an economic standpoint. Unused portions of garbage as well as the resulting hog manure may be used locally for soil improvement.

There appears to be a growing tendency to explore the possibility of returning garbage to land in the form of composts(19,20). It has long been known that garbage, fresh or composted, may be used for soil improvement provided proper precautions are observed. Garbage added to land has sometimes been found to have residual effects more important than the influence upon the first crop grown after application(11).

Today, composts are not often offered for sale in garden supply stores, although a sizeable tonnage of composted animal manures is reported in channels of trade. It seems that interest in garbage compost is widespread, but economic factors have usually prevented much production beyond the pilot-plant stage of operation.

PROCEDURES FOR COMPOSTING

A few modern composting plants are including city trash with garbage. In these plants all materials except massive pieces of metal are passed through a hammer mill and screen previous to composting.

Garbage composting processes have gone through an evolutionary development. A process patented by G. Beccari of Italy in 1920(3) was utilized to some extent in a number of countries, including the United States, over a period of several years, but is now virtually abandoned(4). The process combines initial anaerobic fermentation with a final aerobic stage. A modification of the process that provides for recirculation of gases or of drainage liquors is known as the Verdier process(24).

A multiple-grate digester of the silo type was patented by G. H. Earp-Thomas in 1939(6). This provides progressive passage of material through the equipment. The Frazer process(7) was patented in 1949 by Eweson. It provides a fully mechanized, continuous process operating under aerobic conditions.

The Dano process, developed in Denmark(8), has been used to a limited extent in the United States. Its principal equipment is a long slowly-rotating drum which is charged with the waste organic material. Air is blown in along the entire length of the drum. The Hunter Foundation of California has found this equipment suitable for decomposing varied vegetable wastes and animal manures, but cost of equipment is high.

Composting systems fall into two general classes; those employing enclosures such as listed above, and decomposition in ricks, windrows or open heaps. In Holland extensive composting is in ricks(9). This general type of system is being employed in certain newly established plants in the United States.

The question arises—are inoculants necessary or effective? Some makers of garbage composts prepare or buy cultures of inoculating organisms. In certain cases they feel that additions of such organisms definitely hasten decomposition. On the other hand, the University of California found that garbage as collected is adequately inoculated and that decomposition is not hastened by addition of specific inoculants(21).

The composting process requires air and water (23). Decomposition may be accomplished under anaerobic conditions but the action is relatively slow and the material malodorous. Adequate aeration is usually considered to be essential. It is not easy to accomplish fully aerobic conditions during early stages of processing. Such action is promoted by the presence of fluffy bits of paper, ground corncobs, or soil. The latter tends, of course, to build up a relatively high ash content in the compost.

The moisture requirement for compost formation is not closely defined, but the presence of about 50 to 60 percent of moisture is often desirable for rapid decomposition. The water present has some influence on rate of temperature rise. Temperatures should reach about 150° to 160° F. in three or four days.

COMPOSITION OF GARBAGE AND GARBAGE COMPOSTS

The composting process brings about drastic decrease in the carbohydrate content of garbage and accomplishes varying degrees of decomposition of other organic constituents, with the evolution of carbon dioxide and some loss of nitrogen. Large quantities of nitrogen are transformed into the cells of bacteria(5). Such organisms have been shown to contain about 7 to 11 percent of nitrogen on a dry basis. The tissues of fungi may contain about 4 to 6 percent of nitrogen. Such microbial cells often constitute a substantial part of the mass of a matured compost. Some workers have estimated that as much as 30 percent of the nitrogen may be present in these forms. After a period of several days or a few weeks of composting objectionable odors usually disappear. The product is then of a humus-like nature and is said to be stabilized.

The chemical composition of garbage and of composts derived in considerable part from garbage, varies widely. Table 1 shows the nitrogen contents of garbage from several cities. Some of these values are for single samples and some are based on averages for an indefinite number of samplings.

TABLE 1.—AVERAGE NITROGEN CONTENTS OF RAW GARBAGE FROM SEVERAL CITIES, DRY BASIS.

Location	Nitrogen
	percent
Washington, D. C.(1)	2.70
Hastings, New York(10)	2.20
Yonkers, New York(10)	2.50
Chicago, Illinois(1)	1.24
Savannah, Georgia(22)	1.22
Canton, Ohio(1)	2.08

Since garbage consists essentially of plant and animal products it is well to take a look at a summary of the chemical compositions of such materials. Professor E. Truog and associates of the University of Wisconsin have conpiled the percentage contents of the various elements normally found in whole plants.[2] The values stated below are the percentages, dry basis, of usual occurrence, but are not necessarily average or limiting values.

Element	*Amount Present, Dry Basis* *percent*
Carbon	45
Oxygen	43
Hydrogen	6
Nitrogen	1 - 3
Phosphorus	0.05 - 1.5
Sulfur	0.05 - 1.5
Potassium	0.3 - 6.0
Calcium	0.0 - 3.5
Magnesium	0.05 - 0.7

Minor elements are designated below as parts per million (p.p.m.)

Iron	10 - 1500
Manganese	5 - 1500
Zinc	3 - 150
Copper	2 - 75
Boron	2 - 75
Molybdenum	only a trace

Somewhat less complete data covering the composition of meat products are available through the American Meat Institute(18). The approximate percentages of several elements in meat are as follows:

Element	*Content in Whole Plant* *percent*
Nitrogen	6.8
Phosphorus	.5
Potassium	.8
Calcium	.03
Iron	.01

[2] Soils: Nature and Management. Mimeo. Lectures, Soils Dept. Univ. of Wisconsin; 264 pages. 1947.

SAMPLES OF COMPOST COLLFCTED FOR PRESENT STUDIES

	Material Composted and Location	*Remarks*
1.	Municipal refuse, Berkeley, California	
2.	Garbage, Long Island, New York	
3.	Garbage, Phoenix, Arizona	U. S. Public Health Service pilot plant product.
4.	Garbage, Washington County, Maryland	Residue of a garbage dump decomposed about 2 years on open hillside.
5.	Garbage, Savannah, Georgia	U. S. Public Health Service. Experimental material developed in insulated containers.
6.	Essentially garbage plus some trash, Pittsburgh, Pennsylvania, area	A commercial compost.
7.	A commercial product, Norman, Oklahoma	A compost of city wastes; dominantly material picked up by garbage disposal trucks; developed in a windrow system.
8.	Garbage plus a little soil, from 6 neighborhood homes, Washington, D. C.	No preliminary grinding; composted 5 weeks during hot weather; inadequately aerated during early stages of decomposition.
9.	An experimental sample, Spring Valley, New York	Garbage .... 60 percent Cacao tankage .... 10 percent Wool waste .... 10 percent Soil .... 20 percent
10.	An experimental sample; 50% garbage with much paper, some slaughterhouse offal, 25% soil. Spring Valley, N. Y.	Composting time, 6 weeks.
11.	Garbage processed in a pilot plant, Michigan State University, East Lansing, Michigan	Silo-type composter used.
12.	Garbage processed near Lansing, Michigan	A semicommercial product.
13.	Garbage .... 5200 lbs. Corncobs .... 1000 lbs. Peat .... 300 lbs. Dolomitic limestone .... 80 lbs. Lansing, Michigan	Composted 20 days.

Bones are of much higher phosphorus and calcium content than meat, about 10 percent phosphorus and 23 percent calcium. The nitrogen content is about 4 percent.

Chemical composition of garbage varies widely because of the constituent materials, their quantity and composition. On a dry basis, raw garbage contains about 2 percent nitrogen, 2 percent phosphoric oxide (P_2O_5), and 1 percent potash (K_2O).[3] The national annual plant nutrient supply in urban garbage is probably about 50,000 tons each of nitrogen and phosphoric oxide and about 25,000 tons of potash. These are sizeable tonnages but represent only small percentages of the total plant nutrients consumed as fertilizers in the United States. They correspond to about 2.5 percent of the national consumption of fertilizer nitrogen, 2.2 percent of the available phosphoric oxide and 1.3 percent of the potash(17).

The compositions of various composts derived from garbage and from garbage mixed with other waste organic materials have been reported(1). The wide differences shown in composition are probably due in part to variations inherent in the garbage used, in part to composting method and duration of decomposition, and in part to conditions of storage after preparation.

Garbage composts usually contain 1 to 2 percent of nitrogen. It is possible, however, to reach somewhat higher nitrogen levels. Unpublished data from varied sources covering 98 samples of experimental and commercial composts showed nitrogen contents grouped as follows:

Less than 1 percent	36 samples
1 to 2 perecent	38 samples
2 to 3 percent	20 samples
More than 3 percent	4 samples

The inadequacy of the present knowledge of the composition and behavior of garbage composts made it desirable to collect for study some composts prepared by various methods in different parts of the United States. A brief description of each sample is on preceding page.

Determinations of nitrogen, phosphorus, potassium, ash and pH were made on the samples, and results are given in Table 2.

The ranges of values for constituents are wide: nitrogen varies from 0.44 to 4.11 percent, phosphoric oxide 0.42 to 2.98, potassium oxide 0.22 to 2.50 and ash 13.0 to 80.6 percent. The pH range is 6.3 to 8.1.

The ash contents of 8 of the 13 samples studied exceeded 65 percent; two samples had ash value as low as about 13 percent. It is apparent that a little soil or other mineral matter added to improve aeration or for other reasons, greatly increases the ash in the final product after much of the organic material has been decomposed. Material with an ash content as high as 65 percent will be difficult to market as a commercial product; the organic fraction is too small.

The secondary elements, calcium, magnesium and sulfur, and the minor elements, boron, copper, zinc, manganese and molybdenum, are not considered specifically in this study. It is recognized, however, that

[3] This is equivalent to about 0.87% phosphorus and 0.83% potassium.

such materials are normally present in naturally-occurring organic materials. It may safely be assumed that minor elements are present in composts in variable quantities and that these constituents may be of some value when added to soils that are deficient. The order of magnitude of occurrence of these elements may be assumed to be a little greater than the values shown for whole plants. Oxidation of a part of the carbon compounds originally present would tend to increase the percentage of the remaining constituents.

TABLE 2.—CHEMICAL COMPOSITION OF CERTAIN COMPOSTS PREPARED WHOLLY OR IN PART FROM GARBAGE; ANALYSES REPORTED ON MOISTURE-FREE BASIS.

Sample No.	Location	Total Nitrogen (N)	Phosphoric Oxide (P_2O_5)	Potassium Oxide (K_2O)	Ash	pH
		percent	percent	percent	percent	
1	California	0.44	0.42	0.38	79.2	7.5
2	New York	1.47	2.25	1.63	72.0	7.6
3	Arizona	.83	.88	.76	73.0	7.2
4	Maryland	4.11	2.98	.69	31.5	6.8
5	Georgia	1.54	.70	.80	13.7	7.8
6	Pennsylvania	.63	1.10	.22	80.6	7.4
7	Oklahoma	.92	.60	.55	68.0	8.0
8	District of Columbia	.98	.68	.82	75.8	7.2
9	New York	1.68	.87	.45	66.5	7.4
10	New York	.91	1.98	.65	78.0	6.3
11	East Lansing, Michigan	3.33	2.31	1.56	34.6	6.8
12	Lansing, Michigan	2.64	2.22	2.50	26.5	8.1
13	Lansing, Michigan	2.23	.77	.70	13.0	7.3

TABLE 3.—NITRIFICATION CHARACTERISTICS OF CERTAIN GARBAGE COMPOSTS INCUBATED AT 30°C. FOR 4 PERIODS.

Sample No. and Location	Total Nitrogen (N)	Portion of Total Nitrogen Converted to Nitrate in— 3 Weeks	6 Weeks	8 Weeks	10 Weeks
	percent	percent	percent	percent	percent
2. New York	1.47	0.16	0.22	0.24	0.25
3. Arizona	.83	.26	.41	2.00	4.02
4. Maryland	4.11	3.42	4.12	5.08	6.20
5. Georgia	1.54	.16	1.98	3.22	3.82
7. Oklahoma	.92	1.63	2.54	2.65	3.06
8. District of Columbia	.98	1.79	3.14	4.12	4.41
9. New York	1.68	2.59	3.24	3.82	4.12
10. New York	.91	3.90	5.03	6.15	7.18
11. Michigan	3.33	.55	1.17	1.19	1.22
12. Michigan	2.64	.17	.47	.61	.73
13. Michigan	2.23	1.68	3.62	5.17	6.08

FERTILIZER VALUE OF GARBAGE COMPOSTS

The fertilizer value of organic ammoniates has been determined by several methods, no single one of which serves as an entirely satisfactory index. Conventional chemical analyses, as given in Table 2, provide an inventory of the plant nutrients present. However, such data tell little about the rate of availability of these nutrients to growing plants. Additional data are freqently desirable. These may consist of nitrification rates, plant growth response tests, and uptake of nitrogen by plants.

In the present study, nitrification rates were determined on the samples that contained more than 0.75 percent of nitrogen. The method used was essentially that of Sanford and Hanway(16), devised primarily for determination of nitrification rates of organic matter in soils. Determinations of nitrates were made at intervals of two or three weeks on samples incubated at 30°C. Data are reported in Table 3.

Nitrification rates for the different composts were all relatively low and varied widely. In some cases nitrification was the most rapid during the first 3-week period: in other cases the rates were more rapid later. All of the rates were much lower than those of sewage sludges previously reported(2). Data available from other investigations indicate that the nitrogen contents of composts are not nearly as readily nitrifiable as the nitrogen of seed meals and certain other organic ammoniates normally classed as of good fertilizer quality.

CROP RESPONSE STUDIES

The present investigation did not include crop response studies. Such experiments have been made to a limited extent, however, at other institutions. McCool(11) tested the growth response of several crops to fresh garbage and to garbage composted 2 or 4 days. The availability of the nitrogen present in the organic matter was not increased by composting. In one case a marked lowering of the availability of nitrogen resulted from 4 days of composting. The nitrogen of composts was less available than that of cow manure, as evidenced by lower yields in the first crop of millet. On the other hand, the carry-over or residual effect of the composts was much larger than that of the manure.

Nitrogen Uptake

Prince and Winsor(14) of New Jersey conducted pot experiments using garbage tankage, a non-composted garbage preparation, in comparison with other nitrogenous fertilizers. Selected data from their report are given in Table 4.

In this experiment the average nitrogen recovery in three kinds of plants was 9.6 percent from garbage tankage, 32.6 percent from standard tankage, and 61.5 percent from nitrate of soda. Comparable data are not available for garbage composts. However, the data of McCool(11) indicate one might expect even lesser uptake of nitrogen from composted garbage than from fresh garbage, probably also less than from garbage tankage.

TABLE 4.- PERCENTAGE OF NITROGEN RECOVERED IN BARLEY, RAPE, AND SORGHUM FROM APPLICATION OF SEVERAL SOURCES OF THIS NUTRIENT (14).

	Applied Nitrogen Recovered in—		
	Barley	Rape	Sorphum
Pot treatment	percent	percent	percent
Garbage tankage	9.84	5.46	13.60
Standard animal tankage	39.26	27.93	30.66
Fish	39.31	24.13	27.60
Nitrate of soda	75.49	57.33	51.65
Sulfate of ammonia	71.14	49.46	43.52

GARBAGE COMPOSTS versus OTHER ORGANIC MATERIALS

Studies conducted several years ago indicated that farm manure contributed more nitrogen to land of the United States than all commercial fertilizers taken together (12,13). The nitrogen applied as manure to harvested crops in 1947 amounted to about 26 times the total nitrogen content of urban garbage currently estimated. Farm manures are usually applied on the farm where produced, except in the Western Coastal States where sizeable tonnages are handled in channels of trade. In the Eastern States, home gardeners frequently purchase bagged or packaged manures, but the tonnage thus used is a small part of the total amount produced.

Sewage sludges of the activated type are available in many local markets, but the tonnages sold are very small compared with the total production and use of farm manures.

Seed meals such as cottonseed and soybean meals are excellent carriers of fertilizer nitrogen, but they are also suitable as animal feeds, through which channels they are mostly consumed. The chemical compositions of various natural organics are given in Table 5, the last column of which summarizes the nitrification characteristics.

Large applications of garbage composts, animal manures, and other organic materials may serve as soil conditioners. In heavy soils, improved tilth may be brought about. The very sandy soils of Florida may be improved in waterholding power and in base exchange capacity.

TABLE 5.—NATURAL ORGANIC MATERIALS USED AS FERTILIZERS (MOISTURE-FREE BASIS).

	Nitrogen (N)	Phosphoric Oxide (P_2O_5)	Potassium Oxide (K_2O)	Nitrification Characteristics
	percent	percent	percent	
Garbage composts	1.7	1.4	0.9	Poor
Chicken manure	4.1	3.7	2.3	Fair
Farm manure	1.2	.6	1.2	Poor
Activated sewage sludge	5.6	5.6	.4	Good
Digested sewage sludge	2.0	1.1	.2	Poor
Cottonseed meal	7.0	2.5	1.5	Excellent

MARKET OUTLETS

Mixed fertilizers are purchased for their contents of N, P_2O_5, and K_2O. However, when organics are purchased, less attention is often paid to an analysis of the material. Two schools of thought prevail regarding the agricultural value of organics for soil improvement. One group says they are worth only the value of the plant nutrients commonly shown in a fertilizer analysis. Another group argues that a great deal of added value comes from the decaying of organic materials in the soil. The extent of such value no one knows.

The home gardener has a different viewpoint from that of the farmer. He wants performance and is willing to pay for it. The town gardener with a few hundred square feet of cultivated area usually cannot rotate his land into sod-crops periodically as a farmer would do. Crop residues are often troublesome for the next planting, so low-grade organics such as animal manures, and well-decomposed peat are frequently purchased to supplement commercial fertilizers and to improve the tilth of the soil. Here is one place where garbage composts might find a market, depending on quality and price. Market gardeners may be expected to consume an even larger tonnage than home gardeners, provided price and quality of the material are suitable.

Another possible group of purchasers might be lawn keepers in certain areas. Garbage compost might be incorporated with the subsoil in the establishment of turf. Potting soils used in greenhouses normally contain considerable amounts of organic matter. Garbage compost might supply this need either alone or with other organics.

Organic materials of varying value for soil improvement are frequently available in local stores. One kind may be preferable for use under certain circumstances, while another may be selected for certain soils or for growing particular plants.

Organic materials sold in many garden supply stores vary widely in chemical composition and in their effects when incorporated with soils. In certain respects garbage composts must be competitive with these various materials. Garbage composts are usually of high ash contents while the percentages of fertilizing constituents are relatively low. This means that their main market would be expected to be a local one.

Garden stores of the Washington, D. C. area carry a number of organic materials of different grades, but currently no composts appear to be offered for sale. In certain areas, however, they are known to be procurable; in fact, such samples were obtained for this study. These materials are not sold on a basis competitive with chemical fertilizers, but gardeners are often willing to pay relatively high prices for them.

FUTURE OUTLOOK

Wide differences of opinion prevail regarding the probable costs of production of garbage composts when modern plants are in full production. The economic future of composts as commercial products must depend upon this and other factors about which adequate information is not now available. Consideration must be given to comparative costs in relation to other available organics, kinds of crops grown, prevailing soil types and the proper relationships between organics and chemical fertilizers for best results.

As more composts become available their place in home gardens and market gardens should be worked out on the basis of experience and research. For the near future large tonnages should not be expected in trade. There is enough raw material, however, to make a potential annual production of more than a million tons of compost. It is very doubtful, however, if foreseeable economic conditions justify an estimate of a major portion of the potential tonnage entering the market.

SUMMARY

Composts made wholly or in part from garbage have been prepared in various places on an experimental basis and, to a limited extent as commercial products. It is not difficult to form compost from various organic materials, including garbage, but commercial production presents a variety of problems, only part of which have been solved.

Raw garbage differs in chemical composition, which accounts for wide variations in composts made from this source of organic material. Garbage composts from various parts of the United States have been analyzed, and their rates of nitrification determined. Nitrogen contents vary from 0.44 to 4.11 percent. Nitrification rates of garbage composts are very low, indicating that the fertilizing value of such materials from a nitrogen standpoint should not be very great for the first crop after application. Large applications may, however, favorably affect the physical properties of soils. There appears to be no great difficulty in making garbage composts containing between 1.2 and 2.5 percent of nitrogen. The plant-nutrient contents of garbage composts approximate those of farmyard manure.

Garbage composts may be useful in several ways: (1) in making potting soils, (2) as mulches, (3) for working into soils of various textures, and (4) for improving soils at the time of establishing lawns. When adequate local supplies are available, market gardeners may use these products instead of animal manures and other organics.

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The Effect of Fertilizer Nitrogen on Nodulation, Growth and Nitrogen Content of Several Legumes Grown in Sandy Soils

G. D. Thornton *

Many practical agronomic problems center around the nitrogen economy of leguminous plants. Since 1886 when Hellriegel and Wilforth demonstrated that certain bacteria in association with the legumes were able to fix nitrogen from the atmosphere, there has been considerable speculation as to the amount fixed and the effect of certain factors on fixation.

Previous workers(1,3,4)[1] have shown that some legumes are able to utilize more nitrogen than is normally acquired through the symbiotic mechanism for fixation. However, little reliable information regarding the time when the greatest need for supplementary combined nitrogen occurs in the development of inoculated legumes under field conditions. It has been suggested(6) that this may occur during the initial stages of development with small seeded plants such as clover while with large seeded legumes such as soybeans(2) this condition probably arises during that portion of the growth period when food is being elaborated at a very rapid rate and the fixation process is unable to keep pace with the nitrogen needs of the plant.

Greenhouse experiments(5) demonstrated that soybeans require additional nitrogen for maximum seed yields and that the best time for applying combined nitrogen was at the time of early pod set. It was further demonstrated by tracer techniques that nitrogen applied at this time found its way into the seed while earlier applications went into vegetative growth at the same time reducing the amount fixed from the atmosphere.

The results of two greenhouse experiments and three field experiments, conducted to further evaluate the nitrogen economy of legumes and determine the practical aspects of nitrogen fertilization, are reported here.

EXPERIMENTAL AND RESULTS

Red clover was grown for six weeks in a 3:1 sand-soil mixture in the greenhouse.[2] Applications of $NaNO_3$ and NH_4SO_4 tagged with N of mass 15 were made at planting and 20 days after planting. A series without nitrogen was grown for comparison. The effects of treatment on nodule formation, yield and nitrogen fixation are shown in Table 1.

There was no difference in numbers of nodules on the plants regardless of treatment. However, considerable variation occurred as to size,

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[1] Numbers in parentheses refer to literature cited.

[2] These experiments were carried out at Iowa State College by the author. The assistance of Dr. F. E. Broadbent in making the mass spectrographic analyses of the plant samples is gratefully acknowledged.

TABLE 1.—THE EFFECT OF SODIUM NITRATE AND SULFATE OF AMMONIA ON NODULE FORMATION, YIELD AND NITROGEN FIXATION BY RED CLOVER HARVESTED 6 WEEKS AFTER EMERGENCE.

Treatment			Mean Number Nodules per/plant	Source of Total			
Source	N ppm	Time of Applying		Avg. Yield Grams/pot	N in Plants: Fixed	N in Plants: Added	N Fixed, % of Total
	0		38	0.50	10.2	......	100
$NaN^{15}O_3$	60	at planting	36	1.00	8.6	15.4	35
	60	20 days after planting	32	0.98	5.4	19.6	22
$N^{15}H_4SO_4$	60	at planting	45	1.61	14.3	16.4	46
		20 days after planting	33	0.86	6.8	11.9	37
		L S D (.05)		0.32			
		(.01)		0.54			

TABLE 2.—YIELD AND NITROGEN CONTENT OF RED CLOVER RECEIVING TWO RATES OF NITROGEN FERTILIZATION AT THREE STAGES OF GROWTH.

Treatment		Lbs. N per Acre	Yield Gms per/Pot	Total N Mgms per/Pot
Source	Time of Applying			
Sodium Nitrate	at planting	20	3.99	62.4
		60	4.76	75.3
	10 days after planting	20	3.82	58.8
		60	4.96	74.2
	20 days after planting	20	3.75	58.7
		60	4.72	76.4
Ammonium sulfate	at planting	20	5.16	81.4
		60	4.34	79.7
	10 days after planting	20	3.93	60.5
		60	5.02	78.3
	20 days after planting	20	3.38	54.2
		60	3.65	57.8
None			2.96	49.0
L S D	5%		1.19	17.8
	1%		1.59	23.8

color and distribution on the roots. Nodules on plants receiving supplemental nitrogen were smaller and more widely dispersed on the lateral roots. Where $NaNO_3$ was added they were dull in appearance as compared with the normal pinkish color when N-fixation is actively in progress.

All treatments receiving nitrogen gave yields significantly greater than the check. When the source of nitrogen was NH_4SO_4, and applied at planting, the increase in yield was highly significant. It will also be noted that fixation was stimulated by the addition of NH_4SO_4 at planting.

Another greenhouse experiment, to determine the effect of two rates of applying nitrogen at three dates, resulted in increased yields and larger amounts of total nitrogen for all treatments when compared with the check (Table 2).

The differences resulting from sources, rates and time of application were not statistically significant except where NH_4SO_4 was applied 10 days after planting in which case 60 pounds of nitrogen gave significantly higher yields than 20 pounds.

The effects of nitrogen from KNO_3 on yield, nitrogen content and N-fixation by sweetclover at two calcium levels are shown in Table 3. This experiment was carried out in the greenhouse in small pots using tagged nitrogen of mass 15.[2]

When no nitrogen was applied the yield was 80 percent greater at the high calcium level than at the low calcium level. When nitrogen was applied this difference did not exist. This same trend will be noted with respect to nitrogen content and nitrogen fixed from the atmosphere.

While the amount of nitrogen added was relatively small as compared with the total fixed (about 10 percent) it was probably sufficient to develop a vigorous root system which enabled the plants to better utilize the calcium in the growing media.

This same relation may not hold under field conditions and it cannot be concluded at this time that sweetclover can be satisfactorily grown on unlimed soils with the addition of a small amount of combined nitrogen.

The results of a field experiment with white clover are shown in Table 4. Nitrate of soda and NH_4SO_4 were applied at rates equivalent to 20 pounds N per acre either with the seed or as a top dress immediately following seeding. The nitrogen reduced the numbers of nodules per plant; however, an increase in percentage of nitrogen and total nitrogen in the plants resulted except where NH_4SO_4 was used as top dress. Yields were not significantly affected by nitrogen treatments.

Field experiments with soybeans were conducted at two locations to determine the effects of inoculation and nitrogen fertilization on seed yields of this crop.

Roanoke soybeans were grown at the Suwannee Valley Experiment Station in 1954. The experiment was located on Klej fine sand. The land had a heavy green manure crop of lupine turned under several weeks prior to planting. One ton of calcic limestone and 500 pounds of 0-14-10 fertilizer were applied broadcast just prior to seeding. Inoculation and nitrogen fertilizer treatments together with seed yields are shown in Table 5.

TABLE 3.—YIELD, NITROGEN CONTENT AND NITROGEN FIXATION BY SWEET CLOVER WITH AND WITHOUT NITROGEN FERTILIZER AT TWO CALCIUM LEVELS.

	No Nitrogen		15 Mgm N per/Pot at $KN^{15}O_3$	
	Lo Calcium	Hi Calcium	Lo Calcium	Hi Calcium
Yield per/pot, gms.	1.48	2.65	4.92	4.42
N content, mgms	51	96	135	124
N fixed, mgms	51	96	126	112
Percent of Total N fixed	100	100	93	90

TABLE 4.—EFFECT OF N-FERTILIZATION ON NODULATION, YIELD AND NITROGEN CONTENT OF WHITE CLOVER.

Treatment	Mean No Nodules	Yield Gms/2 Sq. Feet	N-Content	
			Percent	Grams
Check	10.76	34.87	2.77	0.97
Nitrate,* top dress	4.30	42.83	2.92	1.25
Nitrate with seed	2.40	43.53	3.01	1.31
Ammonium,** top dress	6.92	35.72	3.00	1.07
Ammonium, with seed	2.20	40.75	2.97	1.21
L S D .05	3.03		0.14	0.23
.01	4.25			

Nitrogen added at rate of 20 pounds per acre as *Nitrate of soda and **Ammonium sulfate.

TABLE 5.—EFFECT OF INOCULATION AND NITROGEN FERTILIZER ON ROANOKE SOYBEAN YIELDS. SUWANNEE VALLEY EXPERIMENT STATION, LIVE OAK, 1954.

Treatment	Yield of Seed Bushels per Acre
No Inoculation—No Nitrogen	13.7
No Inoculation—Nitrogen Fertilizer*	19.6
Inoculation—No Nitrogen	25.1
Inoculation—Nitrogen Fertilizer*	23.6
L S D (.05)	4.5
(.01)	6.1

* 34 lbs. N per acre as ammonium nitrate at time of planting.

Thirty-four pounds of nitrogen per acre applied to uninoculated beans as ammonium nitrate at time of seeding increased the yield of seed significantly, while inoculation without nitrogen fertilizer resulted in increases that were highly significant as compared to the check treatment. Combining inoculation with nitrogen applications at time of seeding gave no advantage over inoculation alone.

Jackson soybeans were grown in Kanapaha fine sand at the new Horticultural Unit near Gainesville in 1955. Again, treatments involving inoculation and nitrogen fertilizer applications were employed. Two rates of inoculation and nitrogen applied at a single rate at five and seven weeks after emergence significantly increased seed yields, Table 6. Increasing the rate of inoculation failed to give any response in seed yield. Increases in yields were experienced from the nitrogen applications at both dates; however, the increases were not sufficient for satisitical significance.

TABLE 6.—Effect of Inoculation and Nitrogen Fertilizer on Jackson Soybean Yields. Agricultural Experiment Station, Horticultural Unit, Gainesville, 1956.

Treatment	Yield of Seed Bushels per Acre
No Inoculation—No Nitrogen	7.8
Single Rate Inoculation—No Nitrogen	15.6
Double Rate Inoculation—No Nitrogen	15.5
Single Rate Inoculation—N applied 5 weeks after emergence*	17.1
Single Rate Inoculation—N applied 7 weeks after emergence*	19.0
L S D (.05)	6.4

* 34 lbs. N per acre as Ammonium Nitrate.

SUMMARY AND CONCLUSIONS

Greenhouse experiments, involving the use of tagged nitrogen (mass 15) were used to study the effects of combined nitrogen on nitrogen fixation by red clover and sweetclover in soil-sand and sand-clay mixtures, respectively.

A field experiment was conducted to reveal the effect of nitrogen fertilization on the nodulation, yield and nitrogen content of white clover when grown in Leon fine sand. Two experiments were conducted in the field to measure the influence of combined nitrogen on seed yields of soybeans. The Roanoke variety was grown in Klej fine sand at the Suwannee Valley Station in 1954 while the Jackson variety was grown in Kanapaha fine sand near Gainesville in 1956.

Results obtained in these experiments warrant the following conclusions:

1. Moderate applications of nitrogen may be beneficial in establishing clover stands on prepared seedbeds. The nitrogen should be applied at the time of planting, either just prior to seeding as mixed fertilizer or immediately following seeding as top dress. There were no significant differences resulting from the various sources of nitrogen used.
2. Soybeans may be profitably fertilized with supplemental nitrogen and probably the best time for applying the fertilizer is from 6 to 8 weeks following emergence.

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Oxygen Uptake by Lotus Rhizobium as Influenced by pH*

J. H. Smith**

INTRODUCTION

It has generally been considered that different species of Rhizobium will respond differently to various hydrogen ion concentrations. Thorne and Walker(1) reported that some differences in opinion exist but in general the various species of *Rhizobium* are affected differently by acidity but have about the same tolerance to alkalinity. They reported the effects of pH on growth and respiration of *Rhizobium meliloti* and *Rh. japonicum* and found that maximum growth and respiration took place at about pH 7.0 with *Rhizobium meliloti* and *Rh. japonicum.* Growth and respiration decreased sharply on both sides of these figures and approached zero at about pH 4.5 and pH 9.5.

This paper is a report of an investigation of the influence of pH and glucose concentration in the substrate on growth and respiration of three strains of *Lotus Rhizobium.*

EXPERIMENTAL PROCEDURE

Three strains of *Lotus Rhizobium* were tested at six pH values ranging from 4.3 to 9.3 and in two concentrations of glucose to determine optimum growth values as indicated by oxygen uptake which was determined by the Warburg procedure. The strains used were two obtained from Dr. H. H. Hendrickson of Albert Dickenson Company and labeled LC 511A and LC 511C, and one strain obtained from Dr. L. W. Erdman of the U.S.D.A. and labeled 3EOA6.

Strains LC 511A and LC 511C were isolated from birdsfoot trefoil root nodules from plants grown in a red clay soil, pH 7.85, in Center County, Pennsylvania. Strain 3EOA6 was solated from a birdsfoot trefoil plant grown near Riverside, California in an alkaline soil.

The medium used in the Warburg vessels was of the following composition: $CaSO_4 \cdot 2H_2O$, 0.1 gm.; $MgSO_4 \cdot 7H_2O$, 0.2 gm.; NaCl, 0.1 gm.; yeast extract, 1.0 gm. and distilled water, 1000 ml. Glucose at concentrations to make 0.5% and 0.05% in the final medium and 0.2 M. phosphate buffer were autoclaved separately and combined in the Warburg vessels.

The cultures were prepared as follows: Each strain of *Rhizobium* was inoculated onto several large slants of yeast water-mannitol agar with calcium gluconate as the calcium source. When the cultures had grown sufficiently they were stored in the refrigerator until used. Culture 3EOA6 was not retarded by this method of handling and began to respire and grow immediately after being placed in the Warburg vessels,

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but LC 511A and LC 511C had a tendency to decline in activity with storage in the cold, although they were satisfactory for several days.

When preparing the cultures for respiration evaluation, they were removed from the refrigerator and 10 ml. of sterile inorganic medium plus yeast extract was placed in each culture tube. The growth was worked from the surface of the agar with a sterile inoculating needle and the contents of two tubes was placed in a sterile erlenmeyer flask. The culture was then agitated until uniform cell distribution was obtained.

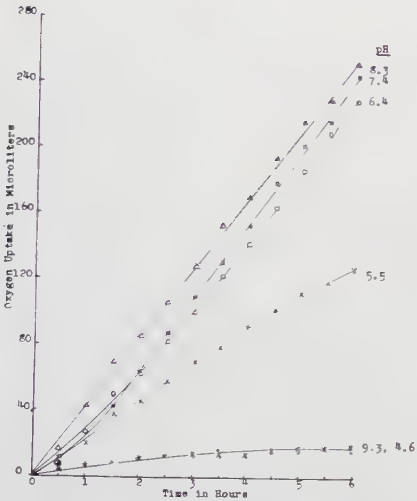

Fig. 1.—Oxygen Uptake Curves Rhizobium 3EOA6, 0.05% Glucose.

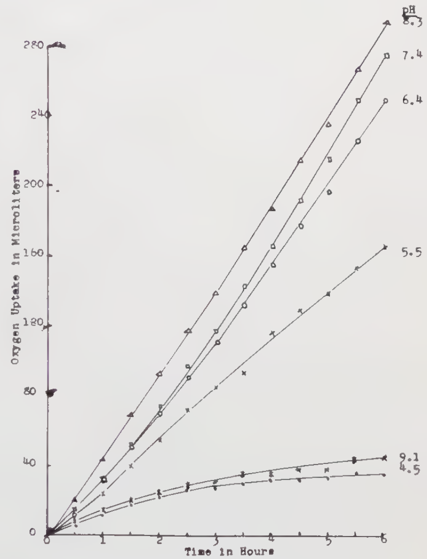

Fig. 2.—Oxygen Uptake Curves Rhizobium 3EOA6, 0.5% Glucose.

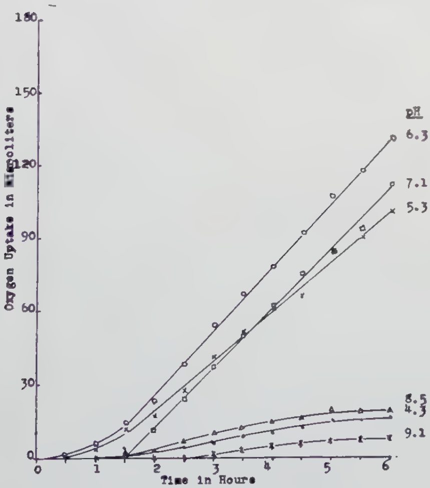

Fig. 3.—Oxygen Uptake Curves Rhizobium LC511A, 0.05% Glucose.

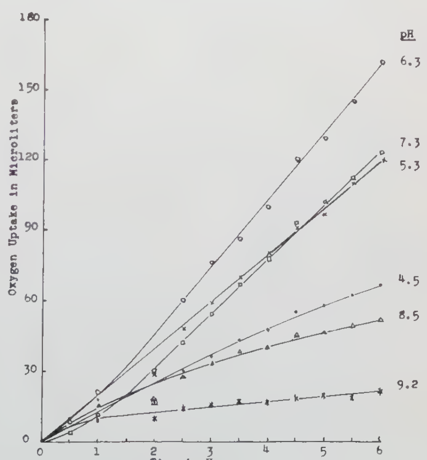

Fig. 4.—Oxygen Uptake Curves Rhizobium LC511A, 0.5% Glucose.

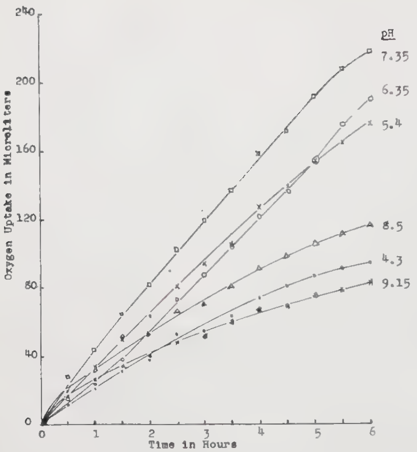

Fig. 5.—Oxygen Uptake Curves Rhizobium LC511C, 0.05% Glucose.

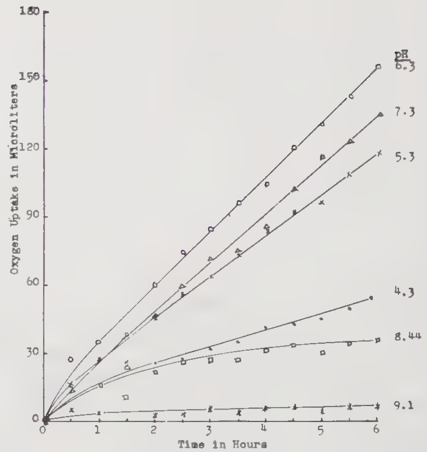

Fig. 6.—Oxygen Uptake Curves Rhizobium LC511C, 0.5% Glucose.

Oxygen uptake was measured using 1.0 ml. of cell suspension, 1.0 ml. of phosphate buffer and 0.5 ml. of glucose solution. Triplicate samples were set up for each pH value which was tested. Two samples were used for respiration and the third was used to determine initial pH. The pH was also determined at the end of six hours of incubation on each sample used in the respirometer. The pH values investigated were about 4.3, 5.4, 6.4, 7.3, 8.3, and 9.1. Variations in pH in general after 6 hours of incubation were less than 0.1 unit from the starting value except at the high pH values where the change was about 0.2 pH units.

Respiration of the organisms was determined at 29.90°C ± 0.01°C. A manometer was used as a thermobarometer to compensate for fluctuations in atmospheric pressure which could not be determined accurately with a mercury barometer.

RESULTS AND DISCUSSION

The results obtained in this investigation were summarized and are presented graphically in Figures 1 through 6. The points on each curve represent the average of duplicate determinations.

Figures 1 through 6 represent the oxygen utilization of *Rhizobium* strains 3EOA6, LC 511A and LC 511C at various pH values and at two glucose concentrations. The difference between optimum pH values for respiration of strain 3EOA6 and the other two strains is very striking. Excellent oxygen utilization was obtained with strain 3EOA6 from pH 6.4 to pH 8.3 with the maximum oxygen utilization at pH 8.3 for both the 0.5% and 0.05% glucose concentrations. Values higher and lower than those indicated gave marked repressions in oxygen uptake and virtually no respiration took place at pH 9.3 or at pH 4.6, at 0.05% glucose. This same picture was true with 0.5% glucose except the upper pH value was 9.1 and the lower value was 4.6.

Rhizobium strains LC 511A had a markedly lower optimum pH value for respiration than strain 3EOA6. This value was pH 6.3. Fairly good oxygen uptake was also exhibited at pH 5.3 and pH 7.1. Values higher and lower than these seriously limited respiration at the 0.05% glucose concentration. This general picture is also true at 0.5% glucose with strain LC 511A.

Rhizobium strain LC 511C had an optimum oxygen utilization at pH 7.35 in 0.05% glucose and at pH 6.3 in 0.5% glucose. The oxygen utilization in 0.05% glucose and pH 7.35 was only slightly higher than at pH 6.35 with the organisms at pH 5.4 following very closely in oxygen uptake. Strain LC 511C appeared to have a greater tolerance for acidity than strain 3EOA6 as determined by oxygen uptake.

Velocity coefficients of growth were calculated, using the 0 to 6 hour respiration values at 0.5% glucose concentration. These data, presented in Table 1, were calculated using the following formula:

$$K = 1/t \ln b/B$$

where K = the velocity coefficient of growth, B = microliters of oxygen utilized per one-half hour at the beginning of time t, and b = the microliters of oxygen utilized per one-half hour at the end of time t, the interval t being taken during the logarithmic period of growth.

TABLE 1.—THE VELOCITY COEFFICIENTS FOR GROWTH (K) OF LOTUS RHIZOBIUM STRAINS LC 511A, LC 511C AND 3EOA6 BETWEEN THE FIRST AND SIXTH HOURS AT VARIOUS pH VALUES.

Strain	pH 4.3	5.3	6.3	7.3	8.3	9.1
3EOA6	0	.112	.231	.135	.032	0
LC 511A	0	.049	.055	.437	0	0
LC 511C	0	0	.102	0	0	0

The *Lotus Rhizobium* are slower growing organisms than some other *Rhizobium* groups. This was noted when comparing the rate of oxygen utilization reported by Thorne and Walker(1) for *Rhizobium meliloti* with the uptake observed for the three strains investigated. The lower respiration rate of the Lotus organism makes it difficult to determine their logarithmic growth phase. Strain 3EOA6 respired more rapidly than the other organisms and some fairly useful "K" values were obtained. The other two strains were slower growing and respired less rapidly than 3EOA6 so only few "K" values were obtainable.

The velocity coefficients for growth are more exact indicators of optimum growth than are respiration figures alone. Strain 3EOA6 had a growth optimum at about pH 6.3 as compared with pH 8.3 optimum for respiration. The other two strains' optimum for growth was nearer their respiration optimum. Strain LC 511A had a growth optimum at pH 7.3 and a respiration optimum at pH 6.3 to pH 7.3 depending on glucose concentration.

Some differences in acid tolerance were noted between the different strains. Strain LC 511C appeared to be more tolerant of acid than either LC 511A or 3EOA6, with the latter showing the least acid tolerance. Conversely, strain 3EOA6 was distinctly more tolerant of high pH than either of the other two strains of Rhizobium.

J. K. Wilson(2) reported the pH in the nodules of *Lotus corniculatus* to be 5.6. This value falls close to the optimum growth range for the organisms investigated.

SUMMARY AND CONCLUSIONS

Three strains of *Lotus Rhizobium* were investigated by Warburg manometric analysis to determine optimum pH values for respiration and growth. Respiration was determined directly. Growth was determined by calculating the velocity coefficients of growth, "K", from the respiration values.

Two strains, LC 511A and LC 511C were found to have optimum growth and respiration in the pH range 6.3 to 7.3. The third strain, 3EOA6, was found to have optimum respiration at pH 8.3 and a growth optimum at pH 6.3.

The following conclusions are drawn:

1. Contrary to some belief, different strains of rhizobia exhibit differences in tolerance of alkalinity.

2. Strains LC 511A and LC 511C appear to have more acid tolerance than strain 3EOA6.

3. The concentrations of energy material used in the reaction vessels had little or no influence on the pH response of the Rhizobium.

4. A difference in respiratory and growth mechanisms probably exists in the different strains of organisms tested. Perhaps strain 3EOA6 developed different mechanisms through being subjected to alkaline conditions in the western soils which produced the plants from whose nodules this rhizobia strain was isolated.

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Amino Acids Found During the Decomposition of Alfalfa and Corn Stover in Soil at Various Temperatures*

Donald F. Rothwell and Lloyd R. Frederick**

Environmental conditions such as temperature, nutrient supply, moisture, aeration, reaction, and the inorganic soil particles influence the rate of soil organic matter formation. Most of the laboratory studies conducted on decomposition of organic residues have been carried out at a constant high temperature (28 - 35° C).

There is general agreement that the nitrogen content of a soil influences greatly its fertility level. It has been observed that soil nitrogen is predominantly organic and that only 2 - 3 percent of the total nitrogen in humid temperate regions is in the inorganic form. Workers have been uncertain as to the amount of soil nitrogen in the form of protein. Kojima(10) working with muck soil reported that no more than 66 - 75 percent of the total organic nitrogen could be considered protein nitrogen. She found that approximately 37 percent of the nitrogen was liberated as α amino-nitrogen by acid hydrolysis.

There is some disagreement as to the similarity of the final products of decomposition. Several workers(1,6,7,15) have reported a similarity in soil organic matter. Bremner(6,7) noted that organic matter formed from a variety of materials and under different conditions tends to attain a rather constant composition with respect to amino acids. On the other hand, some investigators believe that the final products of humus formation vary(8,13,19).

Several investigators(5,6,7,9,12,16) have used paper partition chromatography techniques to study the amino acid content of soils. The soils are usually hydrolized with acid or alkali for a given period prior to separation. Bremner(5,7), using paper chromatography, found the following amino acids in the acid hydrolyzates of soils examined: phenylalanine, leucine, isoleucine, valine, alanine, glycine, serine, threonine, aspartic acid, glutamic acid, arginine, histidine, lysine, proline, hydroxyproline, α amino-n-butyric acid, β-alanine, γ-amino butyric acid and tyrosine. He could not detect cystine, methionine, nor tryptophan. Parker *et al*(12) reported that some of the amino acids found by Bremner(5,7) were not present in any of the soils which they investigated although the amino acids identified were somewhat similar. They found varying amounts of leucine, valine, glycine, threonine, and glutamic acid in all the hydrolyzates of the soils and their fractions. Serine, aspartic acid and lysine were detected in the soils tested and in nearly all the fractions from them. Proline and hydroxyproline, when present, were found only in traces. Arginine was not found in any of the soils and histidine was

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found in two of the three soils examined. The presence of free amino acids in mineral soils has not been demonstrated(7,16).

It is postulated that temperature will cause the decomposition products of plant materials of the same composition to vary. Therefore, the objective of this study was to determine the effect of temperature on the decomposition of plant materials mixed with soil and the variation in the organic matter found under controlled conditions.

MATERIALS AND METHODS

Plant Materials

The corn plant material was gathered in the fall prior to harvest. The plant material, containing 0.75 percent nitrogen (N), 0.05 percent phosphorus (P), 0.45 percent potassium (K), and 0.15 percent sulfur (S), was ground to pass a 2 mm screen. The alfalfa plant material contained 2.55 percent N, 0.205 percent P, 1.85 percent K, and 0.40 percent S. It was harvested at about 50 percent bloom stage, dried and ground to pass a 2 mm screen.

Soil Materials

An A_3 horizon of a virgin Crosby silt loam was selected in order to keep the influence of native organic matter to a minimum. It contained a total carbon content of 0.38 percent of the total oven-dry soil material. The soil was air-dried, crushed to pass through a half-inch screen and thoroughly mixed. This soil required three tons of calcium carbonate per acre to raise the pH from 4.6 to 6.5.

Experimental Methods

One of the objectives of the experiment was to determine the effect of added nitrogen on the decomposition of corn stover. Therefore, the other major elements were adjusted in all treatments to be as nearly the same level as possible. Plant material was added to the soil at the rate of 15 percent (oven dry basis). Sufficient inorganic nutrients were added to balance the additions of nutrients in the various organic materials and thoroughly mixed. The desired moisture was obtained by the addition of finely ground ice from distilled water(14) to 1265 gram portions of the soil-plant mixture. After the addition the mixture was again thoroughly mixed and the alfalfa placed in 2 liter and corn in 4 liter Erlenmeyer flasks. Each flask was inoculated with 1 ml of the filtrate of a heavy suspension of soil taken under a grass sod. The present moisture of the treatments was as follows: alfalfa, 36 percent; corn stover with and without added nitrogen, 40 percent; check 20 percent. Three replicates of each treatment picked at random were placed at controlled constant temperatures of 45°, 60°, 70°, 80°, and 95°F. The incubation was discontinued after 269 days.

The soils were sampled at the end of 12, 26, 89, 150 and 269 days. The treatments at 95°F. were discontinued at the end of 203 days' incubation.

The amino acid content was determined by the modified method of Bremner(4,7). Moist soil, equivalent to 10 gm on an oven-dry basis,

TABLE 1.—Cysteic Acid and Amino Acid Composition for the Alfalfa Treatment.

Incubation Temperature	45°		60°		70°		80°		95°	
Incubation Period Days	12	269	12	269	12	269	12	269	12	*
Aspartic acid	X**	X	X	X	X	X	X	X	X	
Glutamic acid	X	X	—†	X	X	X	X	X	X	
Serine	X	X	X	X	—	X	X	X	X	
Isoleucine	X	X	—	X	—	—	X	—	X	
Leucine	X	X	—	X	—	—	X	—	X	
Phenylalanine	X	X	X	X	X	X	X	X	X	
Tyrosine	X	X	X	—	X	—	X	—	X	
Cysteic acid	X	X	X	X	X	—	X	X	X	
Threonine	—	—	—	—	—	—	X	—	X	
Alanine	—	—	—	—	—	—	X	—	—	
Arginine	—	—	—	—	—	—	—	—	X	
Valine	—	—	—	—	—	—	—	—	—	

* 203 days—temperature went above 95° F.
** Presence of amino acid indicated by X.
† Absence of amino acid indicated by —.

TABLE 2.—Cysteic Acid and Amino Acid Composition for the Corn Plus Nitrogen Treatment.

Incubation Temperature	45°		60°		70°		80°		95°	
Incubation Period Days	12	269	12	269	12	269	12	269	12	*
Aspartic acid	X**	X	X	X	X	X	X	X	X	
Glutamic acid	—†	—	—	X	X	X	X	—	X	
Serine	X	X	X	X	X	X	X	—	X	
Isoleucine	X	—	—	—	—	—	X	X	—	
Leucine	X	—	—	—	—	—	X	X	—	
Phenylalanine	X	—	X	X	X	X	X	X	—	
Tyrosine	—	—	X	X	X	X	X	—	—	
Cysteic acid	X	X	X	X	X	—	X	X	X	
Threonine	—	—	—	—	—	—	X	—	—	
Alanine	—	—	—	—	—	—	—	—	—	
Arginine	—	—	—	X	—	—	—	—	—	
Valine	—	—	—	—	—	—	—	—	—	

* 203 days—temperature went above 95° F.
** Presence of amino acid indicated by X.
† Absence of amino acid indicated by —.

was hydrolyzed 24 hours in 6 N hydrochloric acid at the rate of 4 ml per gram of soil. Interfering salts were removed using ion exchange resins Dowex 2 and Dowex 50. The procedure used was adapted from Stein(17). Following the elution through exchange resins the eluate was evaporated to dryness and taken up with distilled water and saved for spotting on chromatographic filter paper.

The chromatograms were run by the descending method on 18 x 22-inch Whatman No. 1 chromatographic paper in a chromatocab.[1]

The samples were applied to a spot two and one-half inches from the edges of the paper and allowed to dry. A two-dimensional chromatogram was made using a (4:1:5) n-butanol-acetic acid water mixture(11) as the first solvent and water saturated phenol(3) as the second. The papers were thoroughly dried between the use of the solvents. The solvent was allowed to descend until approximately two inches from the bottom of the papers. After thoroughly drying under a hood, the papers were sprayed with a ninhydrin (Eastman) spray and color developed at room temperatures. A mixture of 1.8 gms of ninhydrin, 1800 ml absolute ethanol, 210 ml glacial acetic acid and 72 ml of 2, 4, 6-collidine was made. This was stored in a brown bottle 24 hours prior to use.

The Rf of the indivdual amino acids was determined by obtaining the ratio of the movement of the spot to the movement of the advancing front of the liquid.

RESULTS AND DISCUSSION

The metabolism of the microorganisms may be influenced by the variation in treatments, chemical composition, and temperatures existing during decomposition of added plant material. This may result in a change in the utilization of various compounds which may be reflected in the amino acid composition of the residual material. Therefore, a qualitative study was conducted on the amino acid content of the various soil mixtures on the 12- and 269-day samples. This was done by hydrolyzing the samples with 6 N hydrochloric acid, using a reflux condenser, for 24 hours to break down the complex protein compounds into the various amino acid fractions. Some amino acids may be altered or destroyed during hydrolysis(4,7). It has been reported that acid hydrolysis completely destroys tryptophan, and may partially destroy cystine, serine, threonine, aspartic acid, and glutamic acid.

The amino acid spots on the chromatograms of the various treatments were in agreement with the calculated Rf values of known amino acids (Fig. 1 and Tables 1 - 4). Some variations between Rf values of the pure amino acids and those in the treatment hydrolyzate were found. Temperature, presence of salts and other interfering substances, paper, and type solvents used can cause variation. However, when the chromatograms are run with the same solvent and under similar conditions the Rf values of the treatment should remain relatively constant. The chromatograms of this experiment were run at room temperature due to a lack of controlled temperature facilities. Therefore, it was not possible to keep the temperature constant at all times during the determination.

[1] Chromatocab Model A, Aloe Co., St. Louis, Mo.

The results shown in Tables 1 through 4 indicate the presence or absence of the following amino acids: alanine, aspartic acid, glutamic acid, valine, arginine, tyrosine, leucine, isoleucine and phenylalanine. The presence of cysteic acid was also noted. Although the Rf of cysteic acid was not determined the calculated values of the spots that occurred in this region strongly indicated its presence. This was true when the Rf values were compared with the values obtained by other investigators(2). There were several unknown spots which reacted to ninhydrin that tended to appear in the lower left portion of the chromatograms. These may have been difficultly hydrolyzable peptides or other unidentified biological products.

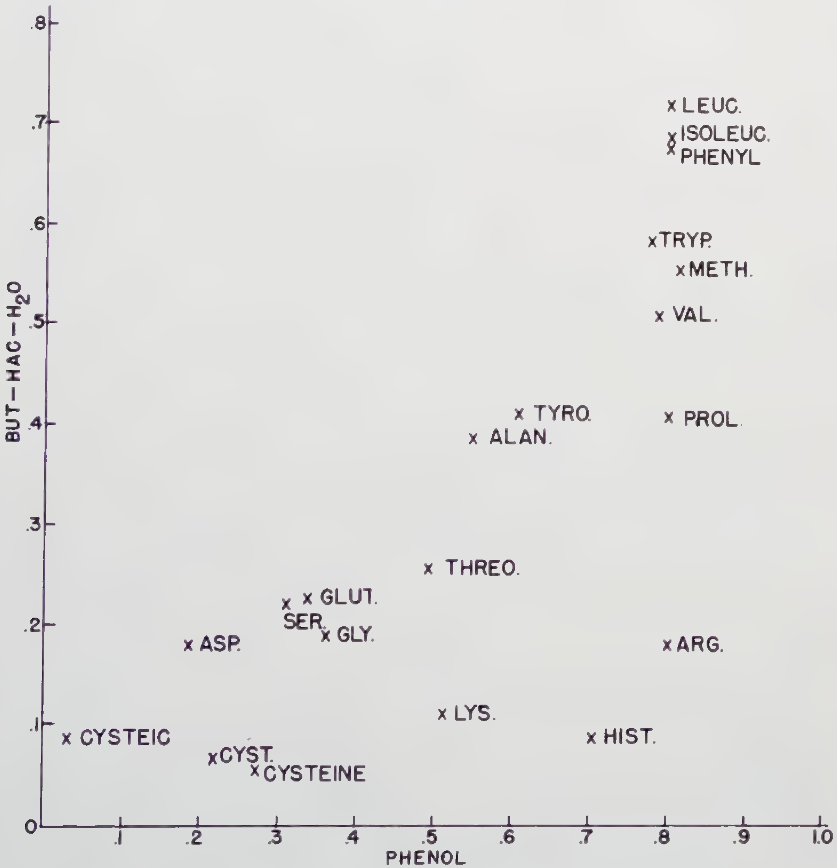

FIG. I R_F VALUES OF CYSTEIC ACID AND KNOWN AMINO ACIDS

It has been reported(18) that amino acids valine, leucine, isoleucine, methionine and phenylalanine may tend to migrate as a group, sometimes forming one large spot on a chromatogram. Therefore, when isoleucine and/or leucine was reported as being present, phenylalanine may have been present even though it apparently was not. The reverse of this

TABLE 3.—Cysteic Acid and Amino Acid Composition for the Corn Alone Treatment.

Incubation Temperature	45°		60°		70°		80°		95°	
Incubation Period Days	12	269	12	269	12	269	12	269	12	*
Aspartic acid	X**	X	X	X	X	X	X	X	X	
Glutamic acid	X	—†	X	X	X	X	X	—	X	
Serine	X	—	X	—	X	X	X	—	X	
Isoleucine	X	—	—	—	X	—	X	—	—	
Leucine	X	—	—	—	X	—	X	—	—	
Phenylalanine	X	—	—	—	X	X	X	—	X	
Tyrosine	X	X	X	X	X	X	X	—	X	
Cysteic acid	X	X	X	—	X	X	X	X	X	
Threonine	—	—	—	—	X	—	—	—	X	
Alanine	—	—	—	—	X	—	—	—	—	
Arginine	—	—	—	—	—	—	—	—	—	
Valine	—	—	—	—	X	—	—	—	—	

* 203 days—temperature went above 95° F.
** Presence of amino acid indicated by X.
† Absence of amino acid indicated by —.

TABLE 4.—Cysteic Acid and Amino Acid Composition for the Check Treatment.

Incubation Temperature	45°		60°		70°		80°		95°	
Incubation Period Days	12	269	12	269	12	269	12	269	12	*
Aspartic acid	—†	—	—	—	—	—	—	—	—	
Glutamic acid	—	—	—	—	—	—	—	—	—	
Serine	—	—	—	—	—	—	—	—	—	
Isoleucine	—	—	—	—	—	—	—	—	—	
Leucine	—	—	—	—	—	—	—	—	—	
Phenylalanine	—	—	—	—	—	—	—	—	—	
Tyrosine	—	—	—	—	—	—	—	—	—	
Cysteic acid	—	—	—	—	—	—	—	—	—	
Threonine	—	—	—	—	—	—	—	—	—	
Alanine	—	—	—	—	—	—	—	—	—	
Arginine	—	—	—	—	—	—	—	—	—	
Valine	—	—	—	—	—	—	—	—	—	

* 203 days—temperature went above 95° F.
** Presence of amino acid indicated by X.
† Absence of amino acid indicated by —.

may also be true. There may be a grouping of serine, glycine and glutamic acid making it difficult to distinguish if this grouping occurred. These groupings are more difficult to separate when working with a material as complex as humus.

Table 1 illustrates the influence of temperature on the composition of humus when alfalfa was used. Aspartic acid was present at all temperatures throughout the incubation period in all treatments. It was noted that tyrosine was present throughout the incubation period at 45° F. and above this temperature it disappeared by the end of 269 days. In the corn-nitrogen treatments (Table 2) tyrosine was absent at 12 and 269, 269, and 12 days at 45°, 80°, and 95° F., respectively. It was present throughout the experiment at the other temperatures. With the corn alone treatment (Table 3) tyrosine remained throughout the incubation period at 45°, 60°, and 70°. At 80° tyrosine was present at 12 days but disappeared at 269 days. It was again present at 95° with the 12-day sample. It was also noted with the alfalfa treatments that phenylalanine was present at 12 and 269 days through all temperatures. In the corn-nitrogen treatments, phenylalanine was absent at 269 and 12 days at 45° and 95°, respectively. With the corn alone treatments phenylalanine was absent at 269, 12, and 269, and 269 days at 45°, 60° and 80°, respectively. It is possible that temperature altered the metabolic requirements of the different groups of organisms present which resulted in the utilization or synthesis of various compounds at one temperature and not another. Therefore, if this occurred it may have caused an alteration in the proteinaceous compounds formed which in turn may be reflected in the composition of the humus.

The chemical composition of organic material added to a soil may also influence the metabolic activity of the various groups of organisms taking part in its decomposition. The results in Tables 1 through 4 indicate that apparently there was a variation in the humus formed from widely diversified materials. The results also indicate that temperature may influence the composition of the soil humus even when formed from the same plant material.

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Soil Microbiological Trends and Their Relation to the Growth of Celery and the Nutrient Status of the Soil*

Charles F. Eno, Philip J. Westgate and William G. Blue**

INTRODUCTION

The addition of organic residues, lime, fertilizers, or other materials to the soil modifies it through their action upon its chemical, physical, and biological properties. Each of these soil properties affects the others in many ways: they, in turn, affect the growth of higher plants. The crop usually is the best measure of soil fertility; however, several microbiological methods of evaluating soil productivity have been employed to advantage(7). An example of these is shown in work by Neller(4) who found that the oxidizing power of the soil varied closely with the average yield for the preceding ten years. There also was a correlation between crop yield, nitrate accumulation, and bacterial numbers, but not crop yield and ammonia accumulation. Noyes and Conner(5) found that, in general, the greater the aerobic bacterial content and nitrifying power of the soil, the larger the crop yields. They concluded that soil fertility investigations should include both chemical and biological measurements of the soil.

Waksman(6), using a sandy loam, observed that crop production paralleled plate counts of microorganisms in the soil. He also found that potassium salts and phosphates stimulated the development of microorganisms and the stimulation was increased by the addition of lime; lime additions alone resulted in a decrease in the numbers of fungi and an increase in numbers of actinomycetes; sodium nitrate stimulated the development of bacteria and actinomycetes but not fungi; ammonium sulfate, which resulted in increased soil acidity, stimulated the development of fungi, and reduced the numbers of bacteria and particularly actinomycetes; ammonium sulfate with lime was equal in stimulating effect to that of sodium nitrate. Waksman concluded that one must find other criteria in addition to numbers of microorganisms to properly determine the microbiological condition of the the soil.

Non-beneficial relationships also can occur. Aberson(1) noted that continuous application of large quantities of commercial fertilizers injured some groups of bacteria, particularly the nitrifying organisms. Anhydrous ammonia injected into the soil with knife-type injectors has also been shown to be toxic to certain of the soil organisms(2). The numbers of fungi and nematodes were reduced progressively by increasing soil levels of ammoniacal nitrogen from 136 to 741 ppm. Compared to untreated soil, only 0.6% of the nematodes and 4.9% of the fungi survived when 608 ppm of nitrogen were present. This much or more ammoniacal nitrogen occurs regularly in the retention zone when anhydrous ammonia is applied in the field. The largest reduction in both nematodes

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and fungi occurred above 365 ppm. Nitrification was also shown to be inhibited by anhydrous ammonia in excess of 300 ppm in the soil. Greaves(3), studying the influence of salts on the bacterial activities of the soil, found that the toxicity of chlorides, nitrates, sulfates, and carbonates of sodium, potassium, calcium, magnesium, manganese, and iron as determined by ammonification was controlled largely by the electronegative ion; as a general rule, the chlorides were most toxic and nitrates, sulfates, and carbonates followed in order of decreasing toxicity. He also stated that it is not necessarily those compounds which become toxic in the lowest concentrations which are the most toxic in higher concentrations; the toxicity of some salts increases more rapidly than the toxicity of others.

In the Sanford area, Westgate, *et al.*(8) showed that Pascal celery yields increased with additions of fertilizer up to approximately three tons per acre, after which a decrease in quality and yield occurred. The purpose of this paper is to point out certain microbiological trends which were closely related to changes in the growth of celery and other soil and plant relationships in the Sanford area.

EXPERIMENTAL METHODS

Pascal celery was transplanted on November 25, 1953, to Leon fine sand with a pH of approximately 5.6. The fertilizer programs were as follows: no fertilizer and 1, 2, 3, 4, and 5 tons per acre of 5-5-8, the formulation of which is shown in Table 1. The fertilizer was broadcast between 30-inch celery rows in ten equal increments, at approximately ten-day intervals beginning December 8, 1953. Treatments were replicated four times; each plot was 1/100 acre. Irrigation was accomplished by raising the water table to within six inches of the surface. After this the wells were turned off and the water was allowed to drain to field capacity to a depth of 12 inches. This intermittent irrigation was carried on throughout the growing season.

TABLE 1.—FERTILIZER FORMULATION.

		Percentage
Total Nitrogen		5.00
Nitrate Nitrogen, not less than	2.00	
Ammoniacal Nitrogen, not less than	1.50	
Water Soluble, Organic Nitrogen, not less than	0.25	
Water Insoluble, Organic Nitrogen, not less than	1.25	
Available Phosphoric Acid, not less than		5.00
Insoluble Phosphoric Acid, not less than	0.10	
Water Soluble Potash, not less than		8.00
Total Available Primary Plant-Food, not less than		18.00
Chlorine, not more than	8.00	
Derived from: Nitrate Soda, Nitroganic Tankage, Ammonium Nitrate, Castor Pomace, Sulfate Potash with Magnesia, Ammoniated Superphosphate and Muriate Potash.		
Total Magnesia as MgO		3.00
Water Soluble Magnesia as MgO	3.00	
Derived from: Sulfate Potash Magnesia.		

Soil samples were obtained from the surface six-inch layer from each plot with a 1½-inch sampling tube: these samples were used for all microbiological studies. Plate counts were made on field-moist soil and computed to an oven-dry basis. Bacteria and fungi were grown on soil extract and rose bengal agar, respectively. All nitrification studies were made from 150 grams of soil adjusted to one-half the water-holding capacity. Thirty mgm. of nitrogen per 100 gm. of soil, as cottonseed meal, were added to the soil to determine its nitrifying potential. The soil was incubated for 28 days at 28 C. Nitrate nitrogen was determined by the phenoldisulfonic acid method (9). A similar procedure was utilized when carbon dioxide evolution was studied: i.e., 30 mgm. of nitrogen as cottonseed meal per 100 gm. of soil was the source of carbon and small tubes of appropriate quantities of standardized sodium hydroxide were employed to collect the carbon dioxide. It was collected for a period of 24 hours on the first, second, third, fourth, seventh, fourteenth and twenty-first days of incubation.

Phosphorus was determined colorimetrically (10) and potassium, sodium, and calcium were determined with a Model B flame spectrophotometer, after extracting the soil by an ammonium acetate (pH 4.8)-soil equilibrium extraction method. Conductivity (Mhos x 10^{-5}) was determined with a Solubridge using one part soil and two parts water, by weight.

TABLE 2.—Amounts of the Various Elements Present in Leon Fine Sand in the Laboratory Study.

Levels	Materials Added (parts per million)				
	N	P_2O_5	K_2O	Ca	Na
0	26	36	78	449	16
1	92	76	283	508	77
2	159	116	489	567	138
3	226	156	694	626	199
4	292	196	900	685	260
5	359	236	1105	744	321

Sources of the Elements:

Nitrogen: ⅗ ammonium nitrogen—from $(NH_4)_2SO_4$. ⅖ nitrate nitrogen—from $NaNO_3$.

Phosphorus: from $CaH_4(PO_4)_2 \cdot 2H_2O$.

Potassium: from KCl.

Calcium: from $CaCl_2$, $CaCO_3$ and phosphorus source.

Sodium: from NaCl and $NaNO_3$.

A laboratory nitrification study designed to corroborate the field results also was conducted. Leon fine sand from the check plots was treated with various combinations of nitrogen, phosphorus, and potassium

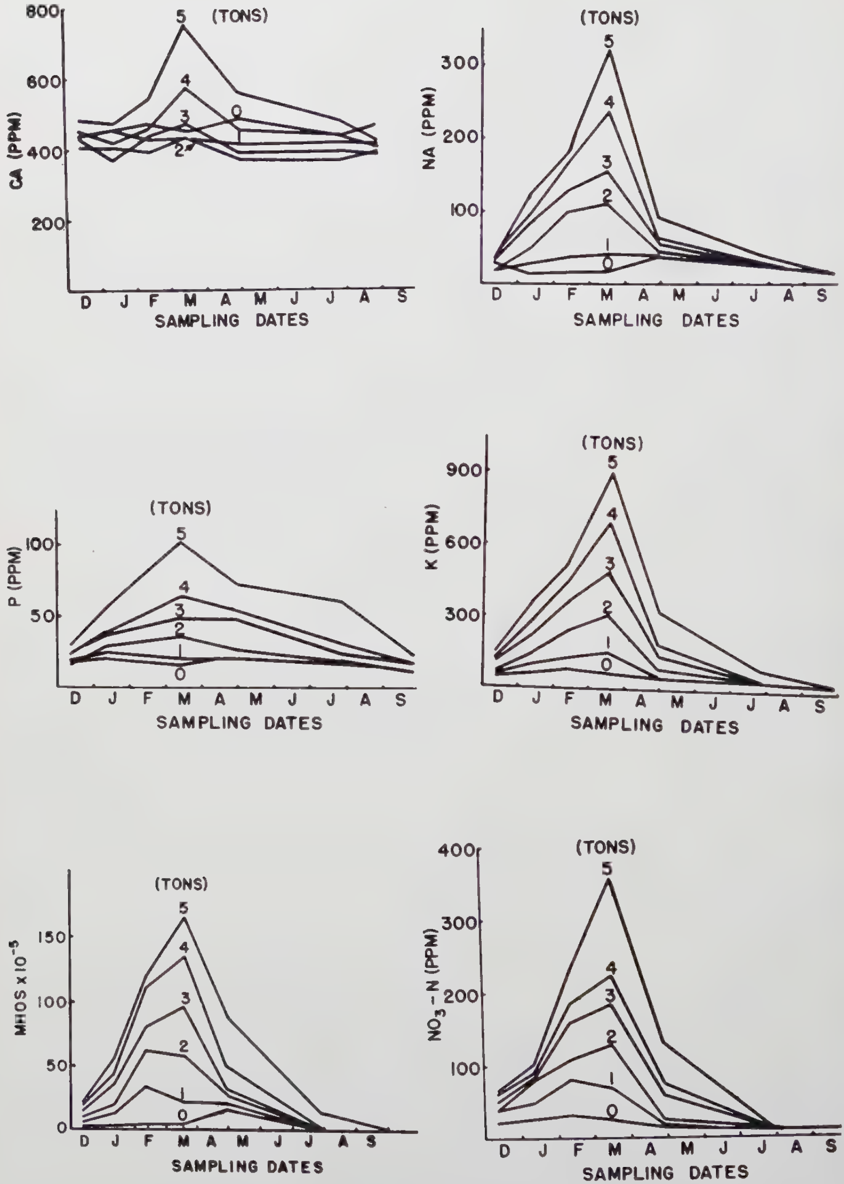


Figure 1.—Conductivity (Mhos x 10^{-5}) and parts per million of nitrate nitrogen, and ammonium acetate (pH 4.8) extractable phosphorus, potassium, sodium, and calcium at five rates of fertilization (from Westgate, *et al.*(8)).

at five levels of fertilization and with calcium and sodium at constant rates in all combinations at each level. Amounts of these elements at each level of fertilization are shown in Table 2. All soils received additional calcium carbonate at the rate of one ton per acre. The combinations of these elements employed are evident from a study of Figure 5. Thirty mgm. of nitrogen per 100 gm. of soil, as cottonseed meal, were added to the soil to determine its nitrifying potential. This experiment was set up in pint milk bottles; each bottle was closed with a bottle cap which had a quarter-inch hole for aeration. The soil was incubated for 28 days at 28°C.

RESULTS AND DISCUSSION

Field Experiment

Soil concentrations of some of the elements and the total salts which occurred during the growing season are shown in Figure 1. Nitrate nitrogen, potassium, and sodium, and to some extent phosphorus and calcium, increased with each added increment of fertilizer. Conductance also increased to 163 mhos x 10^{-5} at the five-ton rate following the last addition of fertilizer.

The yields of Pascal celery and the incidence of blackheart of celery at the various rates of fertilization are shown in Table 3. Celery yields increased through three tons of fertilizer per acre; thereafter the yields declined. Blackheart, a nutritional problem in celery, became progressively more severe with additional fertilizer.

TABLE 3.—Celery Yields and Percentages of Blackhearted Plants at Various Rates of Fertilization.

Fertilizer Applied (tons/acre)	0	1	2	3	4	5
Total Yield (lbs./acre of oven-dry material)	1720	4300	4878	5190	4990	4290
Percentage Blackhearted Plants	4	9	25	47	65	81

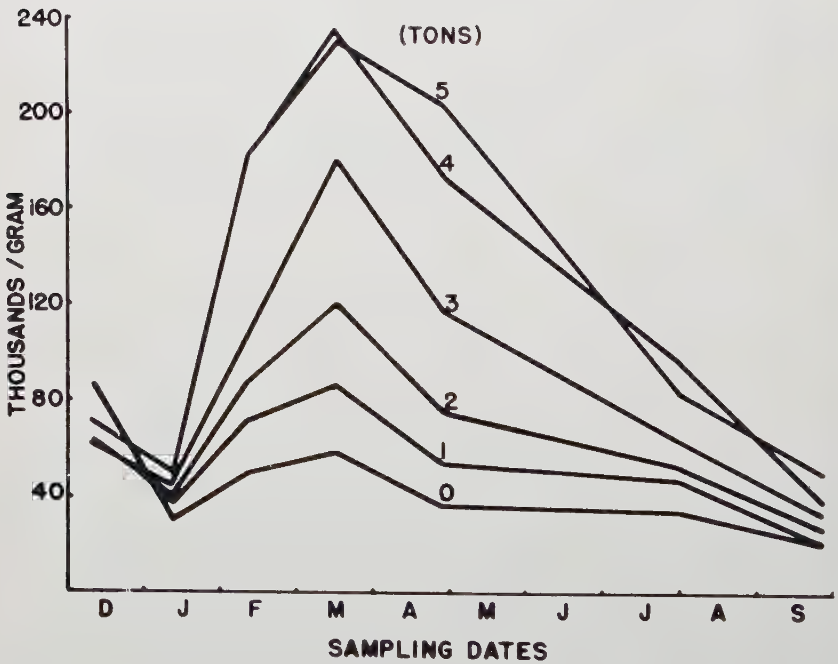
The rate of carbon dioxide evolution from a soil will measure, in part, the activity of microorganisms. Table 4 shows the total carbon dioxide produced from cottonseed meal during seven 24-hour periods of incubation. Carbon dioxide production increased through three tons of fertilizer per acre; further increases in fertilizer decreased carbon dioxide production.

Numbers of fungi increased through the four-ton level (Figure 2). Numbers of bacteria (actinomycetes included)—although not nearly as responsive to fertilizer as the fungi—showed some response (Figure 3). Counts of March and April samplings at the four-ton level were at variance with data for other fertility levels, yet there is little chance that anything other than treatment differences could have caused this variation.

Figure 4 shows the nitrification status of the soil. The upper half of the figure shows the amount of nitrate nitrogen in the soil after 28

TABLE 4.—CARBON DIOXIDE PRODUCED IN LEON FINE SAND.

Rates of Fertilization	Sampling Dates					
	Dec. 12	Jan. 11	Feb. 11	Mar. 16	Apr. 29	Average
(Tons)	(Milligrams per 100 Gms. of Soil)					
0	292	302	295	315	284	298
1	296	321	301	319	300	307
2	304	326	308	325	300	313
3	330	329	318	323	300	320
4	310	312	323	320	309	315
5	240	320	316	316	296	298
					L.S.D. (10% level)	15.2

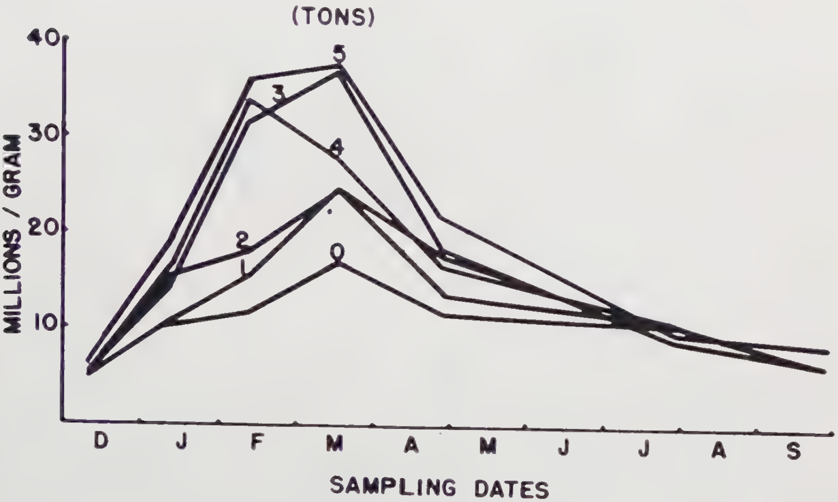


L.S.D. for levels of fertilizer applied at various sampling dates

December	14.4*	March	69.2**
January	14.0**	April	41.0**
February	51.0**	July	28.6**
September	14.4**		

Figure 2.—Numbers of fungi in Leon fine sand at six fertility levels.

days of incubation with no treatments other than those used in the field; i.e., the various rates of fertilization. The lower half represents the potential of these soils to produce additional nitrate. This value was obtained by subtracting the amount of nitrate produced in the field soils from that produced in the same soils which had cottonseed meal added prior to the 28-day incubation period. The nitrification potential of this soil had essentially reached a minimum after the last application of fertilizer at the five-ton rate for only about 2 ppm of additional nitrate nitrogen were produced from the cottonseed meal at this level in March. With the removal of nutrients and other salts by the plants and leaching, the potential for nitrate production increased to between 125 to 150 ppm, a level comparable to that produced in the check soil.

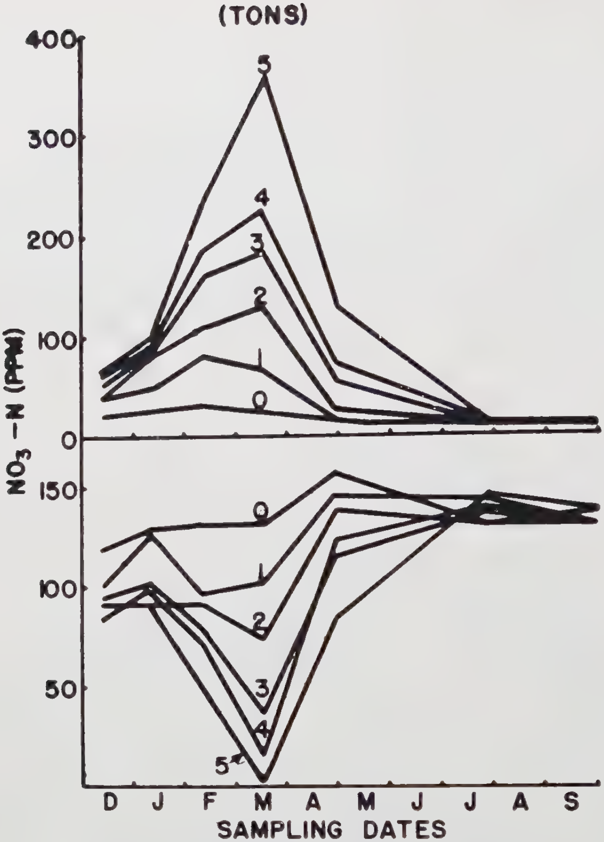


L.S.D. for levels of fertilizer applied at various sampling dates

December	N.S.	March	13.39**
January	3.30**	April	5.21**
February	7.15**	July	N.S.
	September	N.S.	

Figure 3.—Numbers of bacteria (actinomycetes included) in Leon fine sand at six fertility levels.

The fact that (a) celery yields decreased above three tons of fertilizer per acre, (b) carbon dioxide production decreased above three tons per acre, (c) fungi showed little difference in numbers at the four- and five-ton rates, (d) bacterial numbers showed no consistent increase above three tons per acre, and (e) the nitrifying potential was reduced to less than 15 ppm at the four- and five-ton rates, strongly indicates that more than about three tons of this particular fertilizer on Leon fine sand was not beneficial to either the soil population or the celery crop. The chemical data show that nutrient levels and salt concentrations were extremely high after the final application of fertilizer and during the period when the microbial processes were retarded.



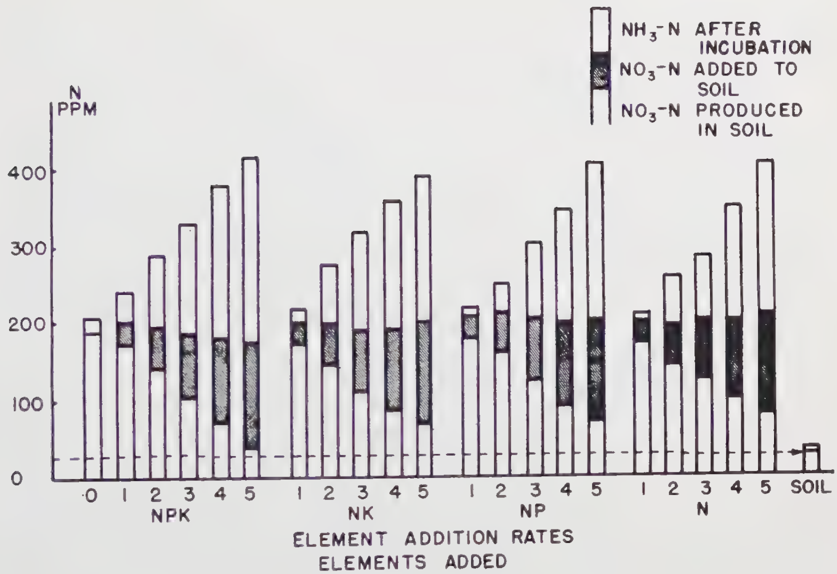
L.S.D. for levels of fertilizer applied at various sampling dates
(For lower half of graph only)

December	25.4*	March	35.8**
January	25.0*	April	N.S.
February	40.4*	July	N.S.
September	N.S.		

Figure 4.—The nitrification potential in Leon fine sand at six fertility levels.

Laboratory Experiment

A laboratory study was conducted to evaluate the effect of various rates and combinations of nitrogen, phosphorus, and potassium on nitrification. Table 2 shows the treatments employed. The No. 5 rate was equivalent to the concentration of these elements present when the greatest accumulation of salts occurred in the field study. The zero level represents the elements present in the Leon fine sand used in the study. Intermediate rates, represented by 1, 2, 3 and 4, are one-fifth, two-fifths, three-fifths, and four-fifths of the No. 5 rate, respectively. Figure 5 summarizes the data from this experiment. The nitrifying potential was reduced to about 12 ppm at the No. 5 rate of the N-P-K treatment, thus essentially repeating the field situation. Figure 5 also shows that the



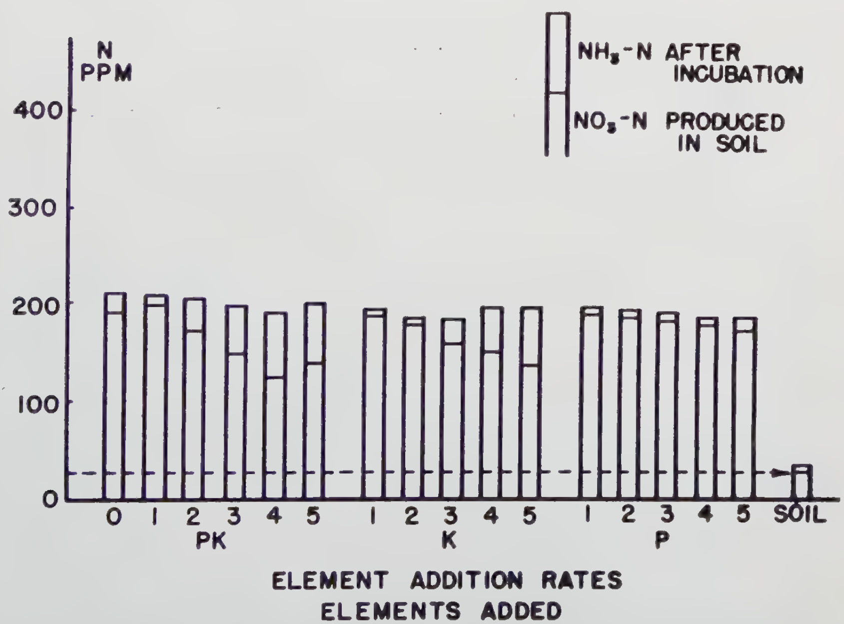


Figure 5.—The effect of various combinations and rates of nitrogen, phosphorus, and potassium, on nitrification in Leon fine sand.

N-K combination reduced the nitrifying potential more than N-P treatment. However, the N treatment showed that the K and P treatments also suppressed nitrification somewhat. That the K treatment suppressed nitrification more than the P treatment is again evident where no nitrogen was added.

The field and laboratory data clearly show that the concentrations of salts resulting from more than three tons of 5-5-8 fertilizer per acre in Leon fine sand caused a reduction in celery yield and carbon dioxide production from the soil. Numbers of fungi increased little above the four-ton rate and the nitrification potential of the soil was reduced to a very low rate at the four- and five-ton levels. The combined data on microbiological and crop growth processes indicate that three to four tons of this fertilizer on Leon fine sand during this particular season was about the level where no further increase in growth occurred. These data point to the need for a careful evalution of the total effect of various fertilizers when applied at high rates.

SUMMARY

A soil microbiological study was made of a Pascal celery fertilizer experiment on Leon fine sand in the Sanford area. The fertilization program was as follows: no fertilizer and one, two, three, four and five tons of 5-5-8 per acre. Celery yield, percentage blackheart of celery, soil nutrient levels, pH, total salts, numbers of fungi and bacteria, total nitrate production, nitrifying potential, and carbon dioxide production were measured.

Results showed that: (a) celery yields decreased when fertilizer was applied in excess of three tons per acre; (b) 47 per cent or more of the celery was affected by blackheart with three tons or more of fertilizer per acre; (c) carbon dioxide production decreased and bacterial numbers showed no consistent increase with fertilizer additions above three tons per acre; fungi showed little difference in numbers at the four- and five-ton rates; and (d) the nitrifying potential was reduced to less than 15 parts per million at the four- and five-ton rates.

A laboratory nitrification study, using various combinations and rates of N, P, and K also showed nitrification to be drastically reduced by heavy applications of the compounds containing these three elements. Analysis of the data showed nitrification to be inhibited in the following orders: NPK>NK>N>NP>PK>K>P.

The combined data for all growth processes indicated that three to four tons of this fertilizer per acre on Leon fine sand during this particular season was about the level where no further increase in growth would occur. These data point to a continuing need for a careful evaluation of the effect of high rates of fertilization on the soil and its microflora, as well as the crop produced.

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CONTRIBUTED PAPERS I

R. W. Ruprecht,* Moderator

Thursday, November 29—1:30 P.M.

Minor Elements Absorbed by Forage Crops Grown on Everglades Organic Soils

Albert E. Kretschmer, Jr.**

INTRODUCTION

The first published report of the need for minor elements by crops grown on the organic soils of the Everglades was reported by Allison, Bryan, and Hunter in 1927(1). Continued research from that time has solved many of the problems associated with minor element deficiencies of vegetable crops. It is now standard practice to supply periodically such elements as copper, boron, manganese, and zinc to vegetable crops and for that reason it is rather uncommon to observe deficiency symptoms of these elements in commercial fields.

On the other hand, minor element nutrition of crops utilized as cattle feed had not been studied until recently(2,3,4) because large-scale production in the Everglades was not initiated until the early 1940's. A deficiency or excess of an element may adversely affect the animal without appearing to affect the pasture crop and conversely, manifestations of anomalies in the crop do not always indicate a potential hazard to the animal. Therefore, the nutrition of forage crops may be considered to be intimately associated with the cattle which graze them and fertilization of such crops with minor elements should be made from a consideration of both plant and animal well-being.

This paper presents a summary of the results of three years research dealing with the contents of minor elements found in pasture crops. Detailed results have been published on copper(5), cobalt(6), sulfur(7), and molybdenum(8,9). Summarization of this work plus additional recent information about some of these elements are presented. Results of iron, zinc and manganese contents of forages are presented for the first time.

Although the iron and zinc results are only of the survey type they are shown in tabular form because such information is not available in the literature (Table 1). More complete information dealing with the absorption of molybdenum by pasture species is shown in Table 2, while results of a soil amendment experiment are given in detail as they show effects of soil additions of sulfur and lime on the molybdenum and manganese contents of forages (Tables 3 and 4).

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MATERIALS AND METHODS

Chemical and physical methods have been published in detail in previous papers. Chemical analyses were made from plant material dried at 70 to 75° C in a forced-draft oven and unless otherwise stated are reported on a unit weight basis. Legume samples consisted of leaves plus petioles of clovers, and above-ground portion of vetch, alfalfa and hubam clover. Grass samples collected for the survey included the following plant fractions: St. Augustinegrass, leaf blades; paragrass and caribgrass, meristems plus leaf blades and stem down to uppermost mature nodes; pangolagrass, youngest portions of plants including leaves, meristems, and stems: Bermudagrass, leaves plus stems; ryegrass and oats, above-ground portion of plants taken 2 to 4 inches above the soil surface. Similar sampling techniques were applied for experimental work with the exception of the greenhouse data presented in Table 2. In this instance pots were clipped to a uniform height and molybdenum analyses were made on the entire sample, or on separate fractions for those samples of which leaves and stems were separated. In the latter instances contents were converted to show the molybdenum content of the whole removed portion.

The data reported in Tables 3 and 4 were derived from an experiment on "old" Everglades peaty muck soil that had been under cultivation for approximately 30 years. Primarily the experiment was designed to determine if any practical means existed of influencing the molybdenum contents of various forages by soil applications of sulfur or hydrated lime. Treatment effects on manganese absorption were also determined. The total soil molybdenum content was 1.1 ppm. A randomized block design with four replications and six treatments was used. The experimental area received a uniform application of 1,200 pounds per acre of 0-8-24 plus 24, 60, 24 and 24 pounds per acre of copper oxide, manganese sulfate, zinc sulfate, and borax, respectively. Sulfur at 1,000 pounds and hydrated lime at 6,000 pounds per acre were then applied to respective plots on November 4, 1954 and disked with the soil. Forages listed in Table 4 were planted to each plot on November 10, after which sulfur at 0 (check), 250, 500, and 1,000 pounds per acre was applied to the surface. Louisiana white clover samples were collected for chemical analyses from all plots on January 18 as were samples of all species from the check plots. The experimental area was mowed and all clippings were removed. All species from all plots were sampled on March 10 (except the St. Augustinegrass which was sampled initially on April 4). The area was again mowed and clippings removed on March 17. White clover and St. Augustinegrass samples were collected for the final time on June 1. Soil samples were collected on April 5, 1955. Certain results of this experiment, published in a previous paper(9), will not be presented here.

RESULTS AND DISCUSSION

Iron and Zinc

Total iron contents of 166 survey samples, including 10 different forages, are presented in Table 1. Except for ryegrass, oats, and alfalfa which contained 122, 144, and 117 ppm iron, respectively; the average

contents were from 64 to 88 ppm. There seems little possibility of iron deficiency appearing in forages grown on the organic soils (author's unpublished data).

Zinc was determined in 18 plant samples, including 8 different species.[1] Contents ranged from 16 to 145 ppm. Because only small quantities of zinc are required for pasture crops(10), it is doubtful if zinc deficiencies could exist under the fertilization program currently being recommended for use on pastures in this area.

Cobalt

In summarizing the work previously reported(6) on the cobalt contents of forage samples collected from different soil types several conclusions may be made.[2] Generally, cobalt levels in both pasture grasses and legumes were very low. Values ranged from 0.01 to 0.26 ppm in the 63 samples collected. More than 75% of the samples contained 0.07 ppm or less and 17 samples contained 0.04 ppm or less. Preliminary investigations indicated that a broadcast application of 6 ounces an acre of 21% cobalt sulfate in a mixed fertilizer disked into the soil was not completely effective in raising the cobalt contents of hubam clover, rygrass, oats, alfalfa, or white clover. Aerial applications at the same rate, not in a mixture, markedly increased the contents of permanent pasture grasses and white clover.

The effects of various surface applications were studied in more detail in an experiment where 21% cobalt sulfate was added to an 0-8-24 fertilizer mixture for application to established Roselawn St. Augustinegrass pastures. Rates of 0, 1, 2, and 3 pounds per acre were applied to each of 5 pastures. Average cobalt contents of samples obtained 40 days after the November 1954 fertilization were 0.08, 0.27, 0.46, and 0.92 ppm, respectively. Further analyses of samples collected about a year later revealed cobalt contents of 0.05, 0.09, 0.06, and 0.07 ppm, respectively. The effectiveness of the soil applications of cobalt had almost completely disappeared during a period of slightly more than a year. Apparently the cobalt is fixed by these organic soils. Because of the expense involved, it is doubtful if soil applications of cobalt sulfate would be economical.

Copper

Additions of copper sulfate or copper oxide at rates of 12 pounds copper per acre have been a standard treatment for virgin organic soils being planted to pasture crops. This application should be disked into the soil because surface applications were found to be rather ineffective. That these soils prevent rapid movement of Cu is indicated by one test in which a Roselawn St. Augustinegrass pasture received a surface application of 50 pounds per acre of copper sulfate. About 5 months later, after the summer rainy season, copper analyses of 0 to 1, 2 to 3, and 3 to 6 inch soil profile samples revealed 180, 2 and 4 ppm total copper,

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[1] Analyses for zinc were made under the direction of Dr. Ivan Stewart, Citrus Experiment Station, Lake Alfred.

[2] Analyses were made by Victor A. Lazar under the direction of Dr. Kenneth C. Beeson, Director, U. S. Plant, Soil, and Nutrition Laboratory, Ithaca, N. Y.

TABLE 1.—THE IRON AND ZINC CONTENTS OF VARIOUS FORAGES GROWING ON EVERGLADES ORGANIC SOILS.

Specie	No. of Samples (Iron)	Iron Range	Iron Average	No. of Samples (Zinc)	Zinc Range	Zinc Average
		ppm	ppm		ppm	ppm
1. R. St. Augustinegrass..	38	38-163	72	6	27-70	39
2. Pangolagrass	13	45-103	81	3	28-145	69
3. Caribgrass	6	56-113	88	1	46	46
4. Paragrass	4	66-98	85	1	35	35
5. Bermudagrass	18	55-160	81	3	16-18	17
6. Fescuegrass	9	46-110	64	....	....	....
7. Ryegrass	13	65-258	122	1	45	45
8. Oats	40	52-188	144	2	34-40	37
9. Alfalfa	7	77-183	117	....	....	....
10. Hubam clover	....	....	....	1	40	40
11. White clover	18	70-120	82	....	....	....

TABLE 2.—THE MOLYBDENUM CONTENTS OF FORAGES GROWN IN THE GREENHOUSE IN "OLD" EVERGLADES PEATY MUCK SOIL.

Specie	Molybdenum Content* 1-26-55	3-14-55	5-9-55	6-24-55	Mean	
	ppm	ppm	ppm	ppm	ppm	ug.
Fescuegrass-Ky. 31	19.9	35.2	16.1	7.9	19.8	(104)**
Fescuegrass-Ky. 19G1-25	12.8	19.1	12.6	4.3	12.2	(75)
Caribgrass	6.2	8.5	13.0	13.0	10.2	(116)
Louisiana White Clover..	6.7	5.4	8.5	16.9	9.3	(91)
Pangolagrass	4.8	6.8	5.0	7.6	6.1	(131)
"Giant" Pangolagrass	3.3	4.1	4.3	3.6	3.8	(73)
Paragrass	3.0	3.7	4.1	3.6	3.6	(29)
Bermudagrass	1.5	4.3	2.3	2.5	2.6	(17)
R. St. Augustinegrass	0.6	1.6	1.5	2.5	1.6	(28)
Pensacola Bahiagrass	1.2	0.7	1.9	2.8	1.6	(31)
Mean	6.0	8.9	6.9	6.5		

Factor	L.S.D.— .05	.01
Variety	2.9	4.0
Date	0.9	1.1
Var. x Date	2.7	3.6

* Average of 4 replications.

** Average micrograms of molybdenum per pot absorbed for 1-26, 5-9, and 6-24 clippings (L.S.D. .05 = 68 ug.).

respectively. In a similar replicated experiment involving surface applications of 12 pounds of copper as the oxide and sulfate on an area of newly planted Roselawn St. Augustinegrass sod pieces, average total copper contents of 0 to 3 inch soil samples were 21 to 31 ppm, but only 2 to 3 ppm in the 3 to 6 inch zone. No consistent differences were noted between the copper contents of the treated and untreated grass (values ranged from about 4 to 7 ppm). The copper was adsorbed in the top zone of soil and since few roots were found in the top inch of soil it was not surprising that the treated grass did not consistently contain more copper than the untreated grass.

Greenhouse tests dealing with the amount of copper that can be absorbed by various species have shown that with applications as high as 1,000 pounds per acre of copper sulfate, Roselawn St. Augustinegrass and Pensacola bahiagrass contained only 18 and 12 ppm copper, respectively. In a field experiment on "old" soil that had received many copper applications over a 30-year period, subterranean clover was found to contain 30 ppm copper while fescuegrass, oats, and hubam clover contained only 12 ppm. In the same experiment ryegrass accumulated 19 ppm. In another experiment, Roselawn St. Augustinegrass and pangolagrass growing on soil that had received an initial application of 100 pounds per acre of copper sulfate disked in the year before the samples were taken contained only 6 ppm copper. In still another experiment on "old" soil that had received many applications of copper, average contents in ppm were found as follows: white clover—12, red clover—19, hubam clover—11, alfalfa—14, vetch—18, and rygrass—18.

Soil pH variations do not appear to influence copper contents to any considerable extent. Application of 1,000 pounds of sulfur per acre or 3 tons of hydrated lime per acre disked into the soil had no effect on the content copper (about 12 ppm) of Louisiana white clover (see Table 3 for soil pH values).

Results from these experiments indicated that large differences exist in the abilities of various species to accumulate copper. At times the copper content of grasses may not reach the 12 to 15 ppm level even when 50 pounds per acre of copper sulfate has been applied to virgin soil.

Molybdenum

Different species and even different varieties growing under similar conditions apparently are able to absorb varying quantities of molybdenum. This point can be illustrated by several examples where the plants were grown under relatively similar conditions in replicated experiments. In one test, molybdenum contents were as follows: bur clover —22, ryegrass—13, hubam clover—13, alfalfa—8, and oats—4 ppm. In another trial the contents were: hubam clover—23, fescuegrass—10, mother white clover—20, Louisiana white clover—16, and fescuegrass—8 ppm. Under greenhouse conditions the ability of different grasses to absorb molybdenum was determined from 4 separate clippings. Results of molybdenum analyses on samples from this experiment are presented in Table 2. Results indicated that Kentucky 31 fescuegrass contained more molybdenum than other species, followed by the other fescuegrass variety and caribgrass. Because of its greater growth and moderate

molybdenum content pangolagrass removed more molybdenum from the soil (131 micrograms) than did other species.

TABLE 3.—Soil pH, Molybdenum and Manganese Contents of Louisianna White Clover and Roselawn St. Augustinegrass, and Manganese Contents of Roselawn St. Augustinegrass as Affected by Soil Applications of Sulfur and Hydrated Lime and by Dates of Sampling.

Treatment *	Soil Depth				Molyb-denum	Manganese	
Material— Rate/A.—Method	0-1	1-3	3-6	0-6	Clover	Clover	Grass
	in.	in.	in.	in.	ppm	ppm	ppm
1. Check	6.0	5.9	5.8	5.9	6.9	18	18
2. Sulfur—250 lbs.—surface	5.9	5.9	5.9	5.9	6.7	20	24
3. Sulfur—500 lbs.—surface	5.8	5.8	5.9	5.8	6.3	25	25
4. Sulfur—1,000 lbs.—surface	5.4	5.9	5.9	5.8	6.4	27	26
5. Sulfur—1,000 lbs.—disked in	5.0	5.7	5.8	5.5	6.4	35	34
6. Hyd. Lime—3 tons—disked in	7.6	6.3	5.9	6.5	8.9	12	22
L.S.D. .05	0.3	0.2	N.S.	0.2	1.7	5	N.S.
L.S.D. .01	0.4	0.3	......	0.3	N.S.	7	....
Replication							
1.	6.0	5.8	5.7	5.7	4.2	26	28
2.	6.0	5.8	5.8	5.8	6.5	21	27
3.	5.9	6.0	5.9	6.0	7.5	21	22
4.	5.9	6.0	6.1	6.0	9.6	22	23
L.S.D. .05	N.S.	0.2	0.1	0.2	1.4	N.S.	N.S.
Dates of Sampling							
January 18	....	....	....	....	5.5	25	....
March 10	....	....	....	....	5.8	26	30**
June 1	....	....	....	....	9.5	17	19
L.S.D. .05	....	....	....	....	0.7	4	7

* Refer to text for fertilization and management data.
** Samples collected April 4, 1955.

Soils cropped for 20 to 30 years still release sufficient molybdenum to grow forages containing as high as 30 ppm. Furthermore, there is some indication that the longer a soil has been under cultivation the greater the molybdenum content of forages growing on it will be even though there is no measurable change in soil pH(8).

Published results(8,9) indicated that molybdenum contents of a particular forage may vary with season. It was found that initial spring samples of legumes such as vetch, alfalfa, and white, hubam, and red clovers contained more molybdenum than samples obtained at a later

date. Samples of five permanent grasses collected in October from a field trial contained an average of 6.5 ppm molybdenum and only 3.4 for those collected in June. No measurable difference in soil pH was found.

Further seasonal effects were noted when molybdenum and copper contents of over 100 survey samples were separated according to acquisition dates from July 1 to January 1 (fall) and January 1 to July 1 (spring). Average molybdenum contents for permanent pasture species were 5.5 and 2.9 ppm and copper contents were 7.4 and 10.9 ppm, for fall and spring samples, respectively. With reference to grazing cattle, the combination of lower molybdenum and higher copper contents in the spring forages would be much more desirable than the higher molybdenum and lower copper contents found in the fall forages(8,9).

Increasing soil pH values resulted in greater molybdenum absorption by forages. Because of the relatively large total molybdenum content of the soil (2.1 ppm average of 30 soil samples analyzed), the potential molybdenum contents of forages were found to be rather large(9). For example in a greenhouse test Louisiana white clover contained 5 ppm molybdenum at a soil pH of 5.5. When lime was mixed thoroughly with the soil to attain pH values of 6.4 and 6.9, the contents were increased to about 14 and 25 ppm, respectively. Maximum absorption occurred between pH values of 6.4 and 6.9. By extrapolation from a curve drawn through points on a graph representing the molybdenum contents of the greenhouse clover at the various soil pH values, a content of about 8 ppm was found when the pH was 5.9 (and a molybdenum content of 8.9 on the curve occurred when the soil pH was about 6.1). This agrees favorably with the field experiment designed to determine whether a practical means existed whereby molybdenum absorption by forages could be influenced by soil applications of sulfur and hydrated lime. The effects of these treatments on the pH within various soil profiles and the molybdenum contents of Louisiana white clover are presented in Table 3. At a soil pH value (0 to 6 inches) of 6.5 the molybdenum content was 8.9 ppm. However, roots penetrating into the 3 to 6 inch soil zone were growing in soil having a pH of only 5.9.

The effectiveness in changing the original soil pH by use of surface applications of sulfur was limited to the 1,000-pound rate and this change occurred only at the 0 to 1 inch depth, while the disked in sulfur and lime applications reacted to a depth of 3 inches. Soil pH values were progressively higher for replications 1 through 4. This effect and the effects of the treatments on the molybdenum contents of Louisiana white clover are presented in Table 3. The lime application resulted in an increase in molybdenum content but none of the sulfur treatments caused a decrease. The effect of replications and sampling dates were outstanding.

Average molybdenum contents, in ppm, of samples collected from the check plots on March 10 for various forages were: Roselawn St. Augustinegrass—1.2, alfalfa—4.9, Louisiana white clover—6.3, Kenland Red clover—6.1, hubam clover—7,3, vetch—13.5, and fescuegrass—4.0. Lime or sulfur disked in had no effect on molybdenum contents of these forages. Average contents, however, were significantly greater on March 10 than on January 18, and increasing soil pH from replication 1 through 4 resulted in increased molybdenum absorption. A single surface or

disked in application of as high as 1,000 pounds per acre of sulfur did not reduce the molybdenum contents of any of the forages. Again, the variation in molybdenum contents among different species was conspicuous. The date of sampling and the variation of soil pH of replications affected molybdenum uptake.

MANGANESE

Manganese contents of 72 samples collected from different fields in the area ranged from 4 to more than 100 ppm. About 20% of these contained 15 ppm or less.

TABLE 4.—THE MANGANESE CONTENTS OF VARIOUS WINTER FORAGES GROWN ON "OLD" EVERGLADES PEATY MUCK SOIL.

Specie	Manganese
	ppm
1. Vetch	27
2. White Clover	26
3. Red Clover	21
4. Fescuegrass	15
5. Hubam Clover	14
6. Ryegrass	14
7. Alfalfa	10
L.S.D. .05	6
L.S.D. .01	8
Date of Sampling	
January 18	17
March 10	17
L.S.D. .05	N.S.

Manganese contents were determined on grass and clover samples collected from the sulfur and hydrated lime experimental plots (Table 3). Sulfur treatments did not affect the contents of Roselawn St. Augustinegrass but 1,000 pounds per acre sulfur disked in resulted in increasing clover manganese contents, while liming decreased the contents. Increasing soil pH of replications had no effect on manganese contents. Contents of both clover and grass samples collected June 1 were significantly less than those of the samples collected earlier.

Manganese contents were determined in samples, collected January 18 and March 10, of seven forage species grown on the check treatment plots. Manganese variation among these species was rather pronounced. All contents were low, especially considering the fact that, in addition to the 60 pounds per acre of manganese sulfate applied at planting, the experimental area had received many manganese applications during approximately 30 years of cultivation. These manganese contents were

much lower than those expected in similarly treated plants grown on the mineral flat wood soils of southern Florida. One of the individual values for alfalfa was as low as 6 ppm manganese. Even so, the alfalfa plants appeared normal. Date of sampling had no effect on manganese contents.

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Effect of Minor Element Sources on the Yield and Composition of Late Staked Tomatoes

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Tomato production in Florida has become a multi-million dollar crop, principally grown for the winter and spring northern markets. The Florida consumer has not been able to purchase vine-ripened fruit in any consistent quantity because both local and out-of-state tomatoes have been picked in the late green, or early pink stages to decrease damage hazards in shipment over long distances and handling. Such fruit have been accused of lacking the flavor found in fruit picked ripe in other areas of the United States. The experiment described in this paper was initiated to determine the effect of minor element materials on the yield and composition of vine-ripened tomatoes grown at the Horticultural Unit near Gainesville.

The composition of tomato fruit has been studied for several elements. In nutrient solutions. Beeson, Lyon and Barrentine(2) found that the calcium content of the fruit was correlated positively with both the supply of calcium and the calcium content of leaflets but negatively correlated to the potassium supply and magnesium supply. Magnesium content of the fruit was not so greatly affected by the magnesium supply as by inverse relationship to the calcium supply, while potassium level had little or no effect. Lyon *et al.*(13) showed that the higher the calcium supply under such conditions, the less blossom-end rot and the more yield occurred. In the above studies, the calcium content of the fruit ranged with treatment from 47 to 172 parts per million fresh weight, whereas the magnesium content ranged from 120 to 206 parts per million and the potassium content from 0.16 to 0.44 per cent. In other solution studies Lyon and co-workers(12) found 0.2 ppm manganese in tomato fruit from plants exhibiting manganese deficiency compared to 1.7 ppm in fruits from control or normal plants; fruit from zinc-deficient plants contained 0.6 ppm Zn compared to 1.9 ppm from healthy control plants; fruit from iron-deficient plants contained 1.4 ppm Fe compared to 3.3 ppm from the control plants; and fruit from plants grown in molybdenum-deficient culture solutions contained 0.01 ppm Mo compared to 0.06 ppm from the complete nutrient media. They reported a mottle red coloring of zinc-deficient fruits and ascorbic acid content was not affected by manganese, zinc, copper or molybdenum in their studies. Brennan and Shive(4) working with tomatoes grown in sand culture found the calcium-boron ratio in leaves of normal plants ranged from 200 to 600; in boron-toxic plants the ratio was 30 to 114; and in boron-deficient plants the ratio was 1,000 to 2,380; soluble boron level was not correlated with soluble calcium levels. Bennett(3) reported iron content of tomato leaves ranging from 90 to 250 ppm, Fe and manganese content from 600 to 10,000 ppm Mn, in solution culture studies. In Australia, Teakle, Morgan and

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Turton(2) observed that copper-deficient tomato leaves were smaller than those from plants receiving 5 to 10 pounds per acre of copper sulfate and had a tendency to roll upwards with the midrib as axis; in addition, yield of fresh fruit per acre was about one-seventh without copper fertilization on the farm studied. Data on tomato composition have been compiled by Beeson(1) and by Goodall and Gregory(10). Sims and Volk(18) analyzed tomato fruit from several soils and found on a moisture free basis that the calcium content ranged from 0.10 to 0.22 percent; magnesium from 0.12 to 0.21 percent; potassium from 3.7 to 5.7 percent; and iron from 0.0032 to 0.0055 percent. Fiskell and Mourkides(8) compared the effect of manganous sulfate, manganous oxide, gamma manganese dioxide and a chelated manganese source on the manganese and iron content of tomato leaves, stems and fruits grown on three soil types. On the Scranton sand liming reduced the manganese uptake more than the iron uptake and manganous oxide was almost as available as manganous sulfate. High phosphate level enhanced the manganese intake. Blossom-end rot occurred only on the unlimed soil in these experiments. Geraldson(9) found that blossom-end rot of tomatoes was a calcium deficiency which could be corrected by spraying with four pounds of calcium chloride per 100 gallons of water. He proposed that soil measures necessary to keep the calcium above 20 per cent in the total soluble salts of the soil should be taken and these included the use of gypsum or superphosphate and avoiding, where possible, topdressings with fertilizer materials which do not contain calcium.

Minor element fertilization of tomatoes has been made in many areas of Florida, partly as insurance against possible deficient soil supply of these nutrients and in some cases where deficiency has been shown to exist. Little information, however, has been available on the optimum rate to apply minor elements or the effect of the applications on tomato quality or yields. Fungicides or other pesticides containing copper, manganese, iron or zinc have commonly been employed and these residues have not been evaluated for their effect on tomato yield or quality. Damage to cantaloupe was reported(6). The present experiment was planned to provide more data on these subjects of minor element rates and of the effect of zinc and manganese carbamate fungicides put in the soil.

MATERIALS AND PROCEDURE

The minor element materials chosen for this experiment were a group of sources having a moderate rate of nutrient release which are the fritted minor elements and the single element experimental bonded granules, a mixture of soluble minor element sources, borax and colemanite. Included as soil treatments were disodium EDTA to test the effect of adding a chelate and the diethyldithiocarbamate of zinc and manganese known under the trade names "Zineb" or "Zinate" and "Maneb" or Manzate" respectively. The latter materials have been added to many soils as residues from rather frequent dust or spray applications to control certain tomato diseases. The minor element contents of the above materials are shown in Table 1. Each treatment material was mixed well with 5-7-5 fertilizer which contained only inorganic nitrogen to avoid the complication of the minor element content of the organic nitrogen sources. Minor

element source and fertilizer rate per 1.000 pounds of fertilizer was as follows: iron sources. 1 lb. Fe: copper sources. 1 lb. Cu: borax 1.1 lb B; colemanite 0.87 lb. B: manganese source 1 lb. Mn; zinc sources, 1 lb. Zn; FN-501 and FN-502 frits. 20 lbs.; Zineb and Maneb fungicides, 50 lbs., or 10 lbs. Zn and 8.3 lbs. of Mn respectively; molybdenum 0.1 lb. Mo; cobalt. 0.1 lb. Co: and EDTA. 20 lbs. Each treatment was applied as a band by a planet Junior on either side of a row of 15 tomato plants, Rutgers variety. spaced one yard apart. Each row was six and one-half feet from the next so that overlap of rooting systems was unlikely. Date of planting was 4/5/56 and that of fertilization and of top-dressing with 300 pounds per acre of nitrate of potash was 4/25/56.

TABLE 1.—Description and Composition of Minor Element Materials and Fertilizer Mixtures.

Material	Description	Composition
5-7-5	Fertilizer mix	Ammonium nitrate, superphosphate, sulfate of potash, dolomite
5-7-5, ⅕ org. N	Fertilizer mix	As above but with 1 unit of N replaced by 0.4 unit of N from cottonseed meal and 0.4 from tankage and 0.2 unit from urea
FN501	Powdered frit*	12.3% Fe, 4.9% Mn, 4.0% Zn, 2.0% Cu, 2.0% B, 0.13% Mo
FN502	Powdered frit*	3.9% Fe, 9.7% Mn, 4.0% Zn, 2.0% Cu, 2.8% B, 0.13% Mo
Borax	Commercial grade	11.3% B
Colemanite	Commercial, 20-40 mesh	8.7% B
Boron granule No. 83	Source bonded** to rock	0.5% B
Copper granule No. 91	Source bonded** to rock	5% Cu
Zinc granule No. 21	Source bonded** to rock	5% Zn
Manganese granule No. 72	Source bonded** to rock	5% Mn
Molybdenum granule No. 73	Source bonded** to rock	0.5% Mo
Cobalt granule No. 123	Source bonded** to rock	0.5% Co
Iron granule No. 20	Source bonded** to rock	5% Fe
Iron granule No. 72	Source bonded** to rock	5% Fe
Minor element mix	Sulfates of Cu, Zn, Mn, borax, neutral iron,† sodium molybdate	4% Cu, 4% Zn, 4% Fe, 4% Mn, 4% B, 0.1% Mo
Zineb or Zinate	Fungicide, zinc diethyldithiocarbamate	76.0% active ingredients, 19.7% Zn
Maneb or Manzate	Fungicide, manganese diethyldithiocarbamate	76.0% active ingredients, 17.8% Mn
EDTA	Chelating agent	Disodium salt of ethylenediamine-tetra-acetic acid.

* Manufactured by Ferro Corporation, Cleveland, Ohio.

** Manufactured by Minnesota Mining and Manufacturing Company, St. Paul, Minnesota.

† Manufactured by Tennessee Corporation, Atlanta, Georgia.

The soil type was Kanapaha fine sand, a phosphatic soil, which had been cleared the previous summer on the Horticultural Unit near Gaines-

ville. This soil was acid, pH 5.3 before planting and averaged pH 5.0 adjacent to the tomato plants after harvest. Two dustings with DDT were made but no other pesticides were used.

Most of the growing season was dry except in mid-June. Rainfall recorded at Gainesville was as follows: March, 0.88 inches; April, 3.11; May, 4.12; June, 11.33; and July 5.55. The plants were watered lightly at planting and 0.5 inch of water was applied on May 20.

Harvesting of ripe fruit and of all stages of fruit having blossom-end rot was begun twice a week from 6/11/56 to 7/30/56. Chemical analysis was run on ripe fruit gathered 7/5/56 and on young leaflets from ten or more plants collected 7/25/56. Soil samples were also taken on the latter date but chemical data from these are not reported in this paper.

Chemical composition of washed fruit was determined on about a kilogram of fruit taken first to dryness and then wet-ashed with nitric-perchloric acid. Dry weight of leaflet samples was obtained and without grinding these samples were wet-ashed. Ash was taken up in 2 N HCl and transferred to a volumetric flask, with rinsings with 2 N HCl up to a volume of 200 ml. for fruit and 100 ml. for leaflet samples. Aliquots were used for the various analyses. After removal of iron and aluminum, calcium was separated as oxalate by double precipitation and determined by permanganate titration using all precautions advised by Kolthoff and Sandell(11). Magnesium was analyzed by the polyacrylate-thiazole yellow method of Mehlich(14). Phosphorus was run using the reagents prescribed by Sherman(17). Iron was determined by the o-phenanthroline procedure(16); manganese by the periodate method after removal of chloride(16); copper as biquinolate complex(5); zinc by the carbamate-dithizone method(7), and molybdenum as the thiocyanate complex in iso-amyl alcohol(16). Taste panel on ripe fruit was conducted by giving fruit of three or more treatments to each participant and grading on the basis of flavor, acid-taste and other comments.

RESULTS AND DISCUSSION

Plant Growth.—Dry, hot weather prevailed during most of the first six weeks. Growth was retarded and plants were small and spindly. This was common to all treatments in varying degrees although the check was least affected. During this period leaves were smaller than normal, had a bluish-green cast, and were slightly rolled but without the marginal scorch usually found for high salt content in the soil or fertilizer burn. These symptoms were not unlike those exhibited by molybdenum-deficient tomato leaves(15) but molybdenum sprays on a portion of the plants, or molybdenum in the fertilizer had no visual effect on the symptom. After sufficient rainfall, growth became rapid and the leaves were more normal in appearance. Fruit ripened almost a month later than in nearby irrigated areas and plant growth continued for several weeks longer than in these areas. Sweet corn in an adjacent area also showed retarded growth during the droughty period. Considerable shedding of older tomato leaves occurred near the end of the harvesting period.

Fruit Yield and Quality.—All of the fruits were weighed and the number of fruits and those damaged by blossom-end rot were counted. In most pickings, insect damage, blossom-end rot and cracking amounted

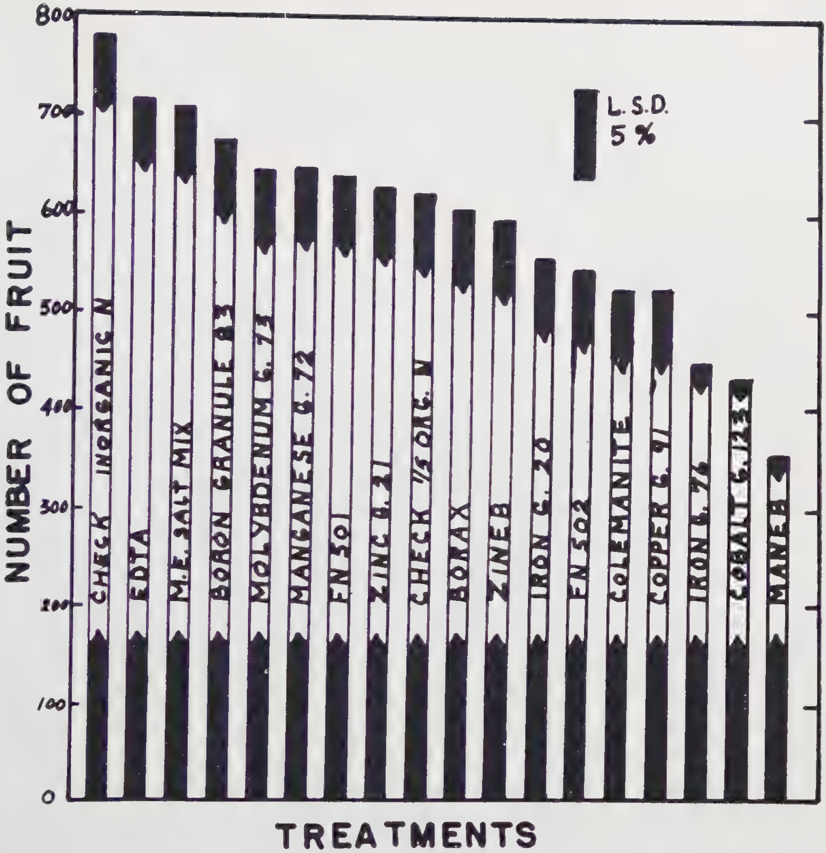

Figure 1. Effect of minor element materials on the number of tomato fruit grown on Kanapaha fine sand.

to nearly 40 per cent of the weight. The undamaged fruits were eaten by members on the taste panel and other members of the Experimental Station staff. The effect of treatment[1] on the number of fruits is shown in Figure 1 and these data are based on 30 plants. The treatment numbers are shown in Table 2. The treatment fertilized with Maneb reduced the number of fruits to 45 per cent of that of the check and significantly lower than all except the cobalt treatment. For the cobalt treatment, less fruits were produced than all except treatments Nos. 9 and 7. All treatments produced less fruit than the check with all inorganic nitrogen except where EDTA and the minor element mix were used. Check treatment with one-fifth of the nitrogen in organic form produced less fruit than treatment 1 or 15, but more than those of treatments 7, 9, 12, 13, or 17. Explanation for this was obscure but the fact that production of fruit was lower in early pickings than where all inorganic nitrogen was used on adjacent rows, as shown in Figure 2, indicated that the factor operating

[1] The least significant differences were determined by the multiple range test advised by Dr. D. B. Duncan.

TABLE 2.—Tomato Fruit Quality, in Terms of Taste of Ripe Fruit, Occurrence of Blossom End Rot, and Chemical Composition.

Treatment No.	Minor Element Source and Rate per 1,000 Lbs. of 5-7-5 Fertilizer*	Taste Panel		Blossom End Rot	Chemical Composition (Fresh Fruit Basis)						
		Number of Trials	Taste Rating**		Ca	Mg	Fe	Mn	Zn	Cu	P
				%	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	Check, inorg. N	23	3.9	31.3	40.2	80	3.13	1.09	1.16	0.23	170
2	Check, ⅕ org. N	14	4.2	33.6	43.3	82	3.25	1.07	1.10	.28	181
3	FN501 frit, 20 lbs.	9	3.8	29.6	38.2	74	4.21	0.92	1.20	.42	195
4	FN502 frit, 20 lbs.	10	3.8	52.3	44.9	92	4.58	1.44	1.54	.40	226
5	Boron gr. No. 83, 20 lbs.	19	3.9	30.2	43.0	88	3.93	0.67	1.25	.22	168
6	Zinc gr. No. 21, 20 lbs.	8	3.8	49.6	34.8	84	5.00	0.76	1.28	.28	201
7	Copper gr. No. 91, 20 lbs.	11	3.6	31.7	40.7	77	4.32	100	1.00	.42	200
8	Iron gr. No. 20, 20 lbs.	15	3.5	35.8	40.0	41	4.88	0.87	1.20	.19	214
9	Iron gr. No. 76. 20 lbs.	12	4.0	19.7	45.7	74	4.22	1.24	1.32	.22	197
10	Molybdenum gr. No. 73, 20 lbs.	7	4.0	32.0	38.6	92	4.07	1.10	1.42	.32	213
11	Manganese gr. No. 72, 20 lbs.	15	4.0	22.9	41.9	105	3.01	1.36	1.60	.27	178
12	Cobalt gr. No. 123, 20 lbs.	4	4.3	17.0	43.6	79	4.07	0.82	1.15	.25	188
13	Colemanite, 204 mesh, 10 lbs.	5	3.8	27.4	41.9	69	4.46	1.41	1.07	.26	175
14	Minor element salt mix., 20 lbs.	4	3.8	39.6	43.2	69	3.83	1.61	1.39	.52	192
15	EDTA, disodium salt, 20 lbs.	11	4.8	30.1	37.6	67	3.35	1.04	1.13	.29	184
16	Zineb, fungicide, 50 lbs.	14	2.2	46.8	33.4	86	4.53	1.42	1.60	.45	217
17	Maneb, fungicide, 50 lbs.	9	3.6	30.2	35.7	71	4.78	1.74	1.21	.33	193
18	Borax, 10 lbs.	6	3.0	38.5	40.0	77	3.89	0.81	1.17	.25	187
	L.S.D. at 5% level			18.9	6.2	23	1.05	0.46	N.S.	.07	N.S.
	L.S.D. at 1% level			26.0	N.S.	N.S.	N.S.	N.S.	N.S.	.09	

* All treatments received 1,000 lbs. per acre of 5-7-5 fertilizer and a side dressing of 300 lbs. per acre of potassium nitrate except treatment 2 which received 4-7-5 plus 1 unit of organic nitrogen plus the same side-dressing.

** Taste panel rating: 5 for flavour rating excellent or delicious, 4 for very good, 3 for good, 2 for tasteless or too acid taste, 1 for objectionable taste such as very acid.

to reduce number of fruit and yield for other treatments might also be involved in this treatment.

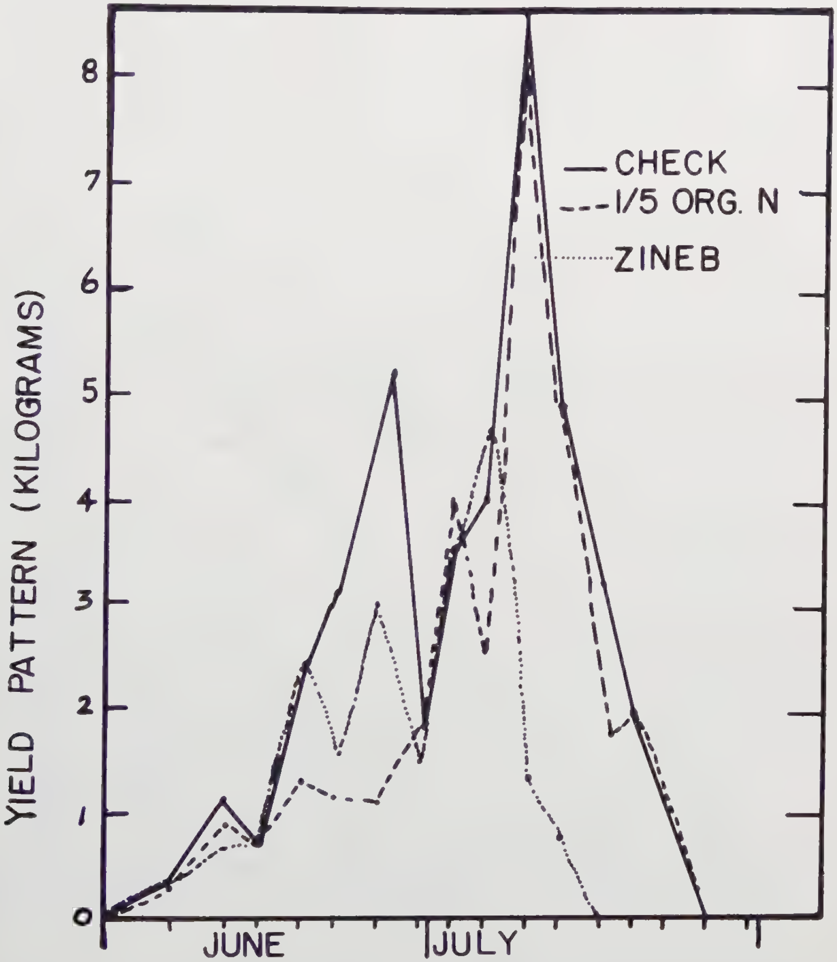

Figure 2. Pattern of yield of fruit for check treatments and for zinc diethyldithiocarbomate (Zineb) in the fertilizer in adjacent rows.

In commercial production, damage by blossom-end rot, insects and diseases would likely be less than in this experiment so that fruit numbers and yield would be closely related. In the present studies total fruit weight is shown in Figure 3 and the percentage of blossom-end rot in Table 2. Fruit yields for the check treatment with all inorganic nitrogen were significantly greater than all treatments except where FN-501 or minor element mix was used. Treatment 14 produced a higher yield than all except treatments 1, 3, and 15. Treatment 3 was significantly larger than all treatments except 1, 2, 10, 14, 15, and 18. Treatment 15

gave more yield than treatments 4, 8, 12, 16, and 17. Maneb gave less yield than all except FN-502 and Zineb. Zineb gave less yield than all except treatments 4, 12, 16, and 17. Apparently FN-502 was at too high a rate because it produced less yield than all except treatments 8, 9, 12, 16 and 17, and this was due in part to this treatment having such a high percentage of blossom-end rot.

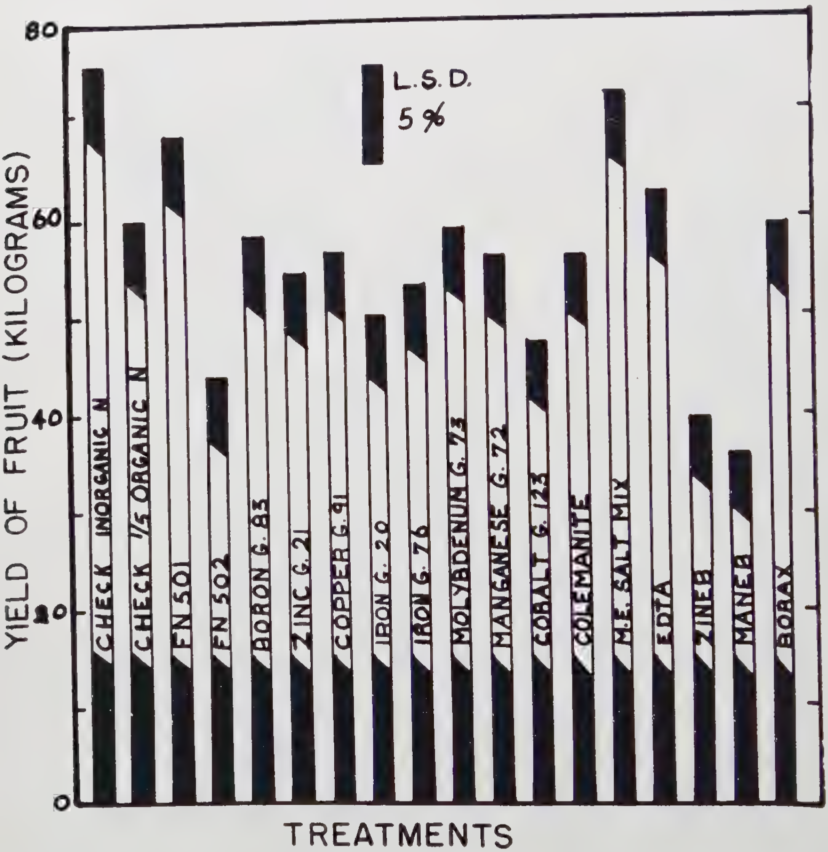

Figure 3. Effect of minor elements on the total yield of tomato fruit grown on Kanapaha fine sand.

Blossom-end rot was the most serious factor in reducing potential yields. Statistically the check treatments were not different from the other treatments in the degree of occurrence. Cobalt granule No. 123 and iron granule No. 76 were lower in the incidence than FN-502, zinc granule No. 21 and Zineb. By observation the former treatments came into production later than the others and it was observed that the earlier pickings contained a high percentage of tomatoes with blossom-end rot, whereas the later pickings contained none or a low percentage.

Toxicity Symptoms.—Principal symptoms attributed to minor element toxicity were dwarfed plants, smaller leaves which were rolled or slightly

TABLE 3.—EFFECTS OF MINOR ELEMENT MATERIALS ON THE VISUAL PLANT CHARACTERISTICS AND ON THE CHEMICAL COMPOSITION OF YOUNG LEAVES TAKEN AT THE LATTER PART OF THE TOMATO FRUIT HARVEST.

Treat-ment No.	Minor Element Source and Rate per 1,000 Lbs. of 5-7-5 Fertilizer*	Plant Appearance Leaf Symptoms 6-14-56		Stunted Plants (7-5-56)	Chemical Composition of Leaves on 7-5-56 (Dry Weight Basis)						
		Roll	Chlo-rosis**		Ca	Mg	P	Fe	Mn	Zn	Cu
				%	%	%	%	ppm	ppm	ppm	ppm
1	Check, inorg. N	None	None	13	1.01	0.47	0.34	182	159	13.4	3.34
2	Check, ⅕ org. N	None	None	30	0.96	0.64	0.35	153	161	13.2	3.40
3	FN501 frit, 20 lbs.	None	None	17	0.89	0.69	0.33	172	172	14.0	5.40
4	FN502 frit, 20 lbs.	None	Slight	57	0.84	0.58	0.34	159	178	13.8	4.17
5	Boron gr. No. 83, 20 lbs.	None	None	27	1.08	0.77	0.34	165	219	11.6	3.47
6	Zinc gr. No. 21, 20 lbs.	Present	Slight	50	0.77	0.60	0.31	146	115	11.8	2.76
7	Copper gr. No. 91, 20 lbs.	Slight	Slight	30	0.63	0.59	0.35	128	138	12.1	4.12
8	Iron gr. No. 20, 20 lbs.	None	Slight	20	1.15	0.39	0.31	158	160	13.3	2.69
9	Iron gr. No. 76, 20 lbs.	None	Present	33	0.83	0.69	0.36	130	176	12.8	3.66
10	Molybdenum gr. No. 74, 20 lbs.	None	None	16	1.00	0.81	0.37	171	154	13.6	3.31
11	Manganese gr. No. 72, 20 lbs.	None	Slight	38	0.84	0.88	0.36	166	240	11.1	3.08
12	Cobalt gr. No. 123, 20 lbs.	Present	Present	37	1.09	0.53	0.32	148	135	12.4	3.17
13	Colemanite, 20-40 mesh, 10 lbs.	None	Present	20	0.83	0.70	0.37	123	150	13.5	2.99
14	Minor element salt mix, 20 lbs.	None	None	3	0.87	0.66	0.29	119	221	12.2	6.35
15	EDTA, disodium salt, 20 lbs.	None	None	20	0.97	0.76	0.33	210	169	14.9	3.02
16	Zineb, fungicide, 50 lbs.	Severe	Present	40	0.88	0.80	0.39	139	233	19.9	4.51
17	Maneb, fungicide, 50 lbs.	Present	Present	40	0.74	0.76	0.36	168	226	14.5	2.78
18	Borax, 10 lbs.	Present	Slight	7	1.05	0.50	0.34	149	169	14.5	2.76
		L.S.D. at 5% level			0.21	N.S.	N.S.	N.S.	46	N.S.	0.84
		L.S.D. at 1% level		N.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1.16

** All treatments received 1,000 lbs. per acre of 5-7-5 fertilizer and a side-dressing of 300 lbs. per acre of nitrate except treatment 2 which received 4-7-5 plus 1 unit of organic nitrogen plus the side-dressing.

** Chlorosis varied from a general yellowish-green to a yellow and slowly increased in occurrence up to 8-2-56 on treatments No. 16, 12, 17 and 11.

chlorotic even in good moisture conditions. This degree is indicated for each treatment in Table 3. The number of plants stunted was undoubtedly a factor in both the number of fruit and weight of fruit. This stunting was attributed to poisoning of the root surfaces by the minor elements. Apparently mass effect of a single element was involved because addition of FN-501 or the minor element mix produced better plants than where single elements were added. Since iron chlorosis symptoms were absent in most cases, the toxicity effect was not sufficient evidently to prevent adequate iron intake by the plant. This was confirmed by the chemical analyses of the fruit and leaves. Where Zineb was put in the soil, a characteristic symptom developed which was a drooping of the top growth, rolling of the leaves, and a spindly appearance; severely affected plants became chlorotic with a pattern like that of iron chlorosis. A symptom attributed to boron toxicity was observed on the plants at the end of the row where boron was put in the fertilizer. These plants received a higher rate of fertilization as the result of slowing the Planet Jr. drill at the ends of the row; plants exhibited spiral fasciation of the stem and petioles.

TABLE 4.—Relationship of Minor Elements and Enzymes in Plants from Data Compiled by Sumner and Somers (19).

Minor Element	Role	Enzyme
Copper	Constituent	Ascorbic acid oxidase, Laccase, Orthophenolase, Tyrosinase
	Inhibitor	Urease, Carboxylase, Asparaginase, Beta-Fructosinase
Borate	Inhibitor	Arginase
Iron	Constituent	Catalase, Peroxidase, Cytochrome Oxidase, Cytochromes, Respiration Enzymes
	Inhibitor	Cellulase
Manganese	Activator	Arginase, Pyruvic Dehydrogenase, Dipeptidase, Carboxylase, Enolase
	Constituent	Arginase
Zinc	Activator	Dipeptidase, Enolase
Cobalt	Activator	Arginase, Pyruvic Dehydrogenase
Magnesium	Activator	Dehydrogenase Coenzyme I, Carboxylase Enolase, Pyruvic Dehydrogenase, Dipeptidase
Calcium	Activator	Succinic Dehydrogenase
Aluminum	Activator	Succinic Dehydrogenase

Taste of Fruit.—The number of individuals participating in the taste panel and the average rating are shown in Table 2. Where Zineb was used a tart but flavorless fruit was produced. This taste was less pro-

nounced in the last pickings which raised the rating from an average of 1.2 in the first ten dates to the final average of 2.2. Acid content, analyzed by Dr. C. B. Hall, was found to be 0.52 and 0.67 where Zineb was the treatment, compared to 0.47 and 0.59 for treatment 2, 0.43 and 0.47 for treatment 14, and 0.41 and 0.64 for treatment 17, respectively, on pickings for 7/10/56 and 7 12 56. This taste factor was not tested by the authors for tomatoes subjected to dust or spray applications of Zineb or other carbamates. Other treatments varied in flavor rating more between individuals than between treatments. The intimate role of minor elements in plant enzyme activity (19) as shown in Table 4, may have accounted for some flavor or taste characteristics and other plant metabolism. Copper would have a definite effect on ascorbic acid oxidase, carboxylase and asparaginase which are necessary plant enzymes. Zinc, iron, manganese, cobalt, magnesium, calcium and aluminum would be involved in many enzyme reactions. However, knowledge of enzyme systems in plants has not developed to the point where fruit quality or nutrient intake can be assigned specific relationships to enzyme activity or minor element supply.

Chemical Composition of Tomato Fruit.—Chemical data on the composition of the fruit are shown in Table 2 as parts per million based on fresh weight. Calcium content was lowest where Zineb, zinc granule No. 21 and EDTA were applied and highest where FN-502, cobalt granule No. 123, iron granule No. 76, boron granule No. 83, the minor element mix and check with organic nitrogen were used. Magnesium content was higher than calcium content and was depressed by iron granule No. 20, and to a lesser extent by colemanite, the minor element mix and EDTA. Iron content was about one-tenth that of calcium and was significantly greater than treatment 1, or check, where FN-501, FN-502, Zineb, Maneb, colemanite and iron granules Nos. 20 and 76, zinc granule No. 21, copper granule No. 91 were added. Manganese content was higher than treatment 1 or 2 where the minor element mix and Maneb were applied and depressed by boron granule No. 83; other differences between sources were significantly different. Zinc content of the fruit was almost as high as that for manganese and highest levels were where FN-502 Zineb, minor element mix, manganese granule No. 72 and molybdenum granule No. 73 were in the fertilizer. Copper content was significantly greater than checks where FN-501, FN-502, minor element mix, Zineb and copper granule No. 21 were employed, but depressed by iron granule No. 20 and there were significantly different levels among other treatments. Molybdenum content of the fruit averaged 5 micrograms per kilogram of fresh weight without molybdenum, compared to a corresponding value of 66 where the minor element mix was used and 46 where molybdenum granule No. 73 was added. Phosphorus content of the fruit was not significantly different between treatments but was high in all cases.

Chemical Composition of Tomato Leaves.—The young leaves were taken for analysis at late stages of the tomato growth. Although these samples may not be representative of plant intake during the season, these data would be indicative of plant intake in the latter part of the productive season which was late July in this case. The data are given in Table 3. Calcium content was statistically lower than check treatment No. 21 where zinc granule No. 21, copper granule No. 91, and Maneb

were applied and was higher than many treatments where boron granule No. 83, borax, iron granule No. 20 and cobalt granule No. 123 were added. Magnesium content was not affected significantly by treatments with plants feeding in the fertilizer band containing a large amount of dolomite. Variation between means for treatments was less than the variation within replicates. Phosphorus content averaged 0.35 per cent P and was not affected by treatments. Iron content averaged 146 parts per million and variation between all means was not significant. Manganese content averaged 168 parts per million and was significantly increased where boron granule No. 83, minor element mix, Zineb, Maneb, and manganese granule No. 72 were used but depressed by zinc granule No. 21. Zinc content was not significantly altered by the treatments but was highest where the Zineb was used and lowest where boron granule No. 83 and manganese granule No. 72 were added. Copper content of the leaves was low and significantly increased where FN-501, FN-502, minor element mix, Zineb and copper granule No. 91 were used. Copper deficiency at this stage of growth might be possible either as a result of deteriorating root systems or withdrawal into the tomato fruit, or both.

CONCLUSIONS

This experiment showed blossom-end rot occurrence when tomatoes are grown on acid soil even in the presence of the comparatively large amount of calcium in the fertilizer and that little help could be expected from B, Co, Cu, Mn, Mo or Zn additions to the fertilizer at these rates. Further, 0.1 per cent of a minor element in the fertilizer evidently was toxic in a dry season when the fertilizer was banded near the plants, although a mixture of the minor elements was not. Maneb and Zineb were found to be toxic when put in the soil and therefore indiscriminate use of these or other pesticides which add heavy metal residues to the soil must be considered as a factor in tomato production, which may be detrimental both to quality and quantity of fruit. From these studies, rate of banded application of FN-501 at 20 pounds per acre might not be excessive but FN-502 should be used at a lower rate, possibly 5 to 10 pounds. Granule sources of banded minor elements were found to be excessively active at the rate of 40 pounds per ton of fertilizer in this experiment. Under the particular conditions of this experiment, the degree and character of the derimental effect of the minor element sources varied depending on the element involved or if a mixture was used. In some cases fruit and leaf composition were found to be altered for elements other than the minor element applied. Rates of application of minor elements in fertilizers to satisfy the nutrient requirement of crops but not to induce toxicity conditions for root systems, will require intensive field experimentation and both soil and plant analysis before optimum levels can be established.

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Effect of Mineral Deficiencies on Yield and Chemical Nature of Certain Crops

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Florida soils frequently are deficient for plant growth in more than one element. These multiple deficiencies make it difficult to be certain that all deficiencies are corrected by a given treatment. A person could very easily apply a general fertilizer to his soil and still have a deficiency such as zinc, sulfur, magnesium or molybdenum for the crop to be grown. The use of high rates of fertilizer in this state could make the unbalanced nutritional condition worse with us than in other states where the general fertility level of the soils is somewhat higher than in our sandy soils. Because of that possibility the writers have been interested not only in the individual deficiencies of our soils, but the effect of the resultant unbalanced nutrition on the chemical composition of the plants grown. This paper will present results of experiments dealing with that subject for crops grown on soil at the greenhouse.

REVIEW OF LITERATURE

No effort will be made to completely review the literature dealing with factors affecting the composition of plant since a number of reviews(3,5,9,12,13,17,18) have been written. However, a few other publications will be emphasized. York *et al.*(19,20) showed a reciprocal relation between calcium and potassium in plants. Hutchings(7) pointed out that a generous supply of calcium increased the calcium and other nutrients in soybeans, not only through increased crop production but through actual enrichment as measured by percentage. Nitrogen(4) stimulated potash absorption by wheat in nutrient solution. This was thought to be related to stimulated top growth and transpiration and not with stimulated root growth. Bartholomew(1) warned against the use of percentage composition of a plant under variations of nutrition when the growth factor which is represented by the amount of dry matter is not considered. Bear and Prince(2) pointed out a tendency of alfalfa towards excessive absorption of potassium which decreased from the second to the eighth crop while the calcium content tended to go up. The idea was expressed that there was a cation-equivalent constancy in alfalfa. Sims and Volk(15) reported little correlation between fertilization and plant composition. Recent work by Taylor(16) for corn grown in nutrient solution definitely showed that the level of magnesium in the nutrient solution affected the general chemical composition of the plant. In more recent years the effect of minor elements(8,10,14) have been emphasized. Steinberg and his associates(14) in this country have shown that minor element deficiencies influence plant composition while Possingham(11) in Australia pointed out that these deficiencies have an important effect on the content of free amino acids in plants.

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EXPERIMENTAL METHODS

General methods which apply to the experiments will be described in this section. Conditions specific to individual experiments will be described under the particular experiment.

The fertilizer treatments were all formulated from reagent grade chemicals, or the best obtainable without repurification. The elimination of a nutrient from a treatment was done by juggling chemicals. For example, calcium can be applied without sulfur through the use of calcium lactate rather than calcium sulfate; or sulfur can be applied without calcium through the use of magnesium sulfate or potassium sulfate in place of calcium sulfate.

Demineralized water was used exclusively throughout the experiments.

In recent years the writers have gone almost completely to the use of soft glass (low boron) containers for growing plants at the greenhouse. These have to be made by our personnel. An explanation of why they are preferred and how they are made should be given at this point.

The type of container is not important in major element experiments, but in minor element ones precautions have to be taken. Soft glass is relatively low in minor elements, including boron. For that reason soft glass containers are suitable for general minor element experiments. Pyrex glass vessels are excellent except that this glass is high in boron. Clean glazed crocks are satisfactory at times, but the glaze is a minor element mixture. Furthermore, glazed crocks check, and the writers have seen hot cleaning solution go completely through them and collect in tiny droplets on the outside. Polyethylene vessels have been used successfully, but some batches are known to have influenced plant growth. Soft glass (low boron) containers, therefore, seem best for general purposes. The main disadvantage is that they break easily.

Suitable inexpensive glass containers were not easy to obtain, but a supply of war surplus bottles ranging in size up to fifteen gallons was found at Camp Blanding. These bottles were obtained and cut into different sizes and shapes as desired. For example, a fifteen gallon bottle was cut into halves. The top portion was inverted, supported by a crock (Figure 1), and when a piece of plastic screen and a soft-glass watch glass were put into the neck to retain the soil, would hold about 60 pounds. That made an excellent container for spreading types of plants. When plants were grown outside on a platform, rains caused leaching. To prevent loss of soluble nutrients the top was taken off a gallon bottle and the bottom part was put in the crock under the neck of the soil container to catch leachings. When there was need for water the leachings were returned to the soil. Gallon size glass containers were stacked as shown in Figure 2. This was done by taking the top off one bottle and the bottom off another, and assembling the two as shown. The bottom part served both as a support and catcher for leachings, while the top part contained the soil.

Intermediate size bottles were managed similar to the large ones. The different sizes were suitable for a variety of plants depending on the nature of growth (Figure 1).

The outside of each container was painted with asphaltum base aluminum paint to keep out light and cut down heat.

Figure 1.—Soft glass containers supported by crocks. Notice different sizes in which several kinds of plants are grown.

Figure 2.—Stacked arrangefent of gallon glass containers in which lupines are growing on Blanton fine sand, level phase. Center, received complete fertilization; others, as shown on labels.

The mineral analysis of the plant material was expressed on a sand-free oven-dry basis. Nitrogen was determined by the Kjeldahl-Gunning method, calcium and potassium by flame-photometry, and magnesium and phosphorus by colorimetric methods. Sulfur was determined by the magnesium nitrate method of the Association of Official Agricultural Chemists.

Experiments with Arredondo Loamy Fine Sand

This soil was obtained from the "Cracker Farm", Florida Agricultural Experiment Station, Gainesville, Florida, in December 1953. No fertilizer had been applied since 1930 and probably little had ever been applied. The pH value of this soil was 5.4 and the relative amounts in pounds per acre of available nutrients were as follows[1]: CaO, 210; Mgo, less than 50; P_2O_5, 39; and K_2O, 84.

An oat and a lupine experiment were conducted on this soil. Forty pounds of soil were put in each container. Since this was not a minor element test, glazed crocks were used. The oats treatments, which were randomized in four blocks, are listed in the tables. The plants were grown outside the greenhouse in the open. On the basis of two million pounds of soil to the acre, the complete oat treatment consisted of the following rates in pounds per acre: NH_4NO_3, 214.3; KCl, 237.6; $Ca(H_2PO_4)_2.H_2O$, 266.4; $CaSO_4.2H_2O$, 500; $MgCl_2.6H_2O$, 125; $CuCl_2.2H_2O$, 5; $ZnCl_2$, 5; $MnCl_24H_2O$, 5; H_3BO_3, 1.25; and $Na_2MoO_4.2H_2O$, 0.3. In the treatment where sulfur was not applied, calcium lactate at the rate of 880 pounds per acre was substituted for the calcium sulfate or an equivalent amount of calcium. In the one treatment with $CaCO_3$ the rate was 500 pounds per acre.

All treatments were applied approximately 2 inches below the surface, except that the $CaCO_3$ was mixed with about the top four inches of the soil.

Fifteen Floriland oat seeds were planted in each container December 18, 1953. They came up well and were thinned to 11 plants per container.

January 6, 1954 two-thirds of the original treatments, except minor elements and $CaCO_3$, were again applied and watered into the soil. There was considerable rain this year, and possibly considerable leaching, so as growth progressed 1⅔ the original ammonium nitrate application and ½ the original KCl and $MgCl_2$ were applied in addition.

The oats were harvested in the late vegetative stage on March 17, 1954, by clipping the plants off as near the soil as possible. The leaf material was dried and weights obtained.

This was to have been the end of the experiment, but the oats stooled, and it was decided to obtain a second harvest.

On April 3, 1954 two-thirds of the original NH_4NO_3 and KCl treatments were applied to the pots. Then 75 pounds of Epsom Salts per acre was applied to block 1 and 2 and none to blocks 3 and 4.

The second crop of oats was harvested on April 27, 1954 after seed formation.

The original fertilizer treatments for lupines were the same as for the oats except ⅗ the amount of nitrogen was applied. The treatments

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[1] All values for available nutrients in this paper courtesy Soil Testing Laboratory, Florida Agricultural Experiment Station, Gainesville, Florida.

were applied in the same manner and were replicated four times in randomized blocks. The lupines were grown in the open outside of the greenhouse.

White seeded sweet yellow lupines were first planted December 18, 1953, but germination was poor. For that reason the seedlings were removed, and the same variety seeded again on December 30, 1953. The seed were innoculated. As soon as a stand was assured, the plants were thinned to five per container.

On January 25, 1954 two-thirds of the fertilizer originally applied was reapplied, except for minor elements and the $CaCO_3$. Ammonium nitrate was applied again at $\frac{2}{3}$ the original amount February 2, 1954.

The lupines were harvested March 30, 1954 and dry foliage yields obtained.

Results of Oat Test on Arredonda Loamy Fine Sand

The plants grew well except the ones without sulfur or without nitrogen. As would be expected, the plants without nitrogen were small and yellow. The ones without sulfur were also yellow (Figue 3). Since yellowing or chlorosis is sometimes associated with minor element deficiencies the blades of some of the plants were streaked with solutions of the following compounds singly and in combination: ferrous ammonium sulfate, ferrous chloride, copper chloride, zinc chloride, manganese chloride, boric acid, and sodium molybdate. The streaking appeared to have no effect.

Figure 3.—Ooats growing on Arredondo loamy fine sand. Right, complete fertilization; left, complete except nitrogen; center, complete except sulfur.

The yellow color of the oats without sulfur was noticeabley changed in 3 days by the application of magnesium sulfate to two blocks of the second growth. The oats became a normal green color in 10 days after the application. As will be seen later the oats did not respond to mag-

TABLE 1.—EFFECT OF FERTILIZER TREATMENT ON MEAN DRY YIELD IN GRAMS OF OATS GROWN ON ARREDONDO LOAMY FINE SAND.

Treatment	Gms. 1st Harvest, Foliage	Gms. 2nd Harvest, Total	Gms. 2nd Harvest, Grain
Complete	83.4	24.4	9.6
Complete except $CaSO_4$	47.4	9.2	3.2
Complete except sulfur	42.9	11.9	2.9
Complete except magnesium	81.6	21.2	7.9
Complete except phosphorus	76.6	22.4	10.0
Complete except nitrogen	5.4	3.7	0.9
Complete + $CaCO_3$	85.7	24.2	9.6
L.S.D. at 5 percent	6.4	5.2	2.1
L.S.D. at 1 percent	8.6	7.1	2.9

TABLE 2.—EFFECT OF FERTILIZER TREATMENT ON MEAN PERCENTAGE OF SULFUR AND NITROGEN IN FIRST HARVEST OF OATS GROWN ON ARREDONDO LOAMY FINE SAND AND MEAN WEIGHTS OF THESE ELEMENTS IN THAT HARVEST.

Treatment	Sulfur		Nitrogen	
	Percentage	Milligrams	Percentage	Centigrams
Complete	.21	178	1.6	129
Complete except $CaSO_4$	.06	26	2.1	99
Complete except sulfur	.07	28	2.2	94
Complete except magnesium	.21	174	1.5	122
Complete except phosphorus	.19	146	1.6	121
Complete except nitrogen	.57	31	1.2	6
Complete + $CaCO_3$	.19	165	1.5	124
L.S.D. at 5 percent	.014	20	0.14	10
L.S.D. at 1 percent	.019	27	0.19	14

TABLE 3.—EFFECT OF FERTILIZER TREATMENT ON MEAN DRY YIELD IN GRAMS OF LUPINE FOLIAGE GROWN ON ARREDONDO LOAMY FINE SAND.

Treatment	Mean Yield in Grams
Complete	48.8
Complete except $CaSo_4$	40.3
Complete except sulfur	40.8
Complete except magnesium	48.7
Complete except phosphorus	49.6
Complete except nitrogen	44.9
Complete plus $CaCO_3$	48.2
L.S.D. at 5 percent	4.7
L.S.D. at 1 percent	6.3

nesium so the change in color was due to the sulfur of the magnesium sulfate.

The yields of oats, both the first and the second harvest, are given in Table 1. It is obvious that neither phosphorus, magnesium, nor cal-

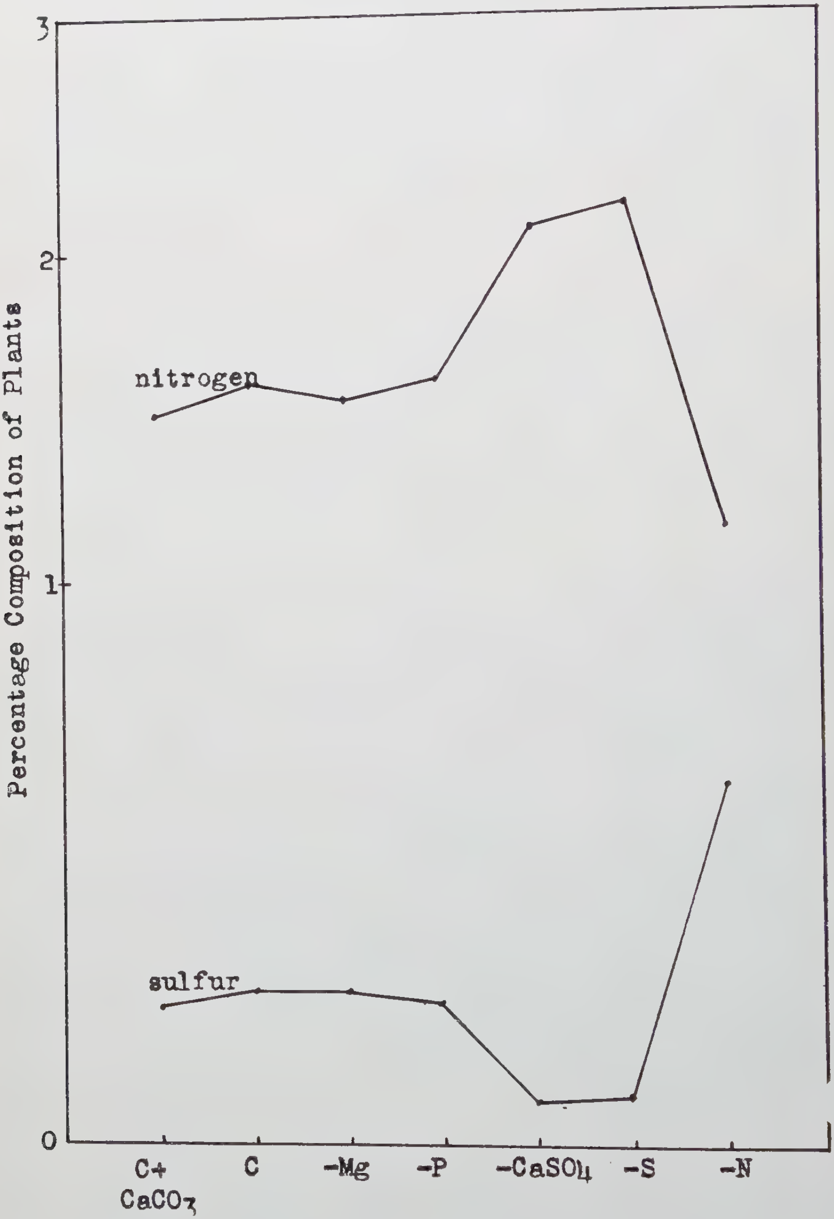

Figure 4.—Variation in Composition of Oats as Affected by Treatment.

cium carbanote had much effect on the yield. Both nitrogen and sulfur greatly increased the yields. Since no fertilizer has been applied to this soil since 1930 it is significant that sulfur rather than phosphorus was the element that greatly increased the yield.

The percentage of sulfur and nitrogen in the first oat harvest as well as the centigrams of these elements in the harvested material are given in Table 2. These values are graphically shown in Figures 4 and 5.

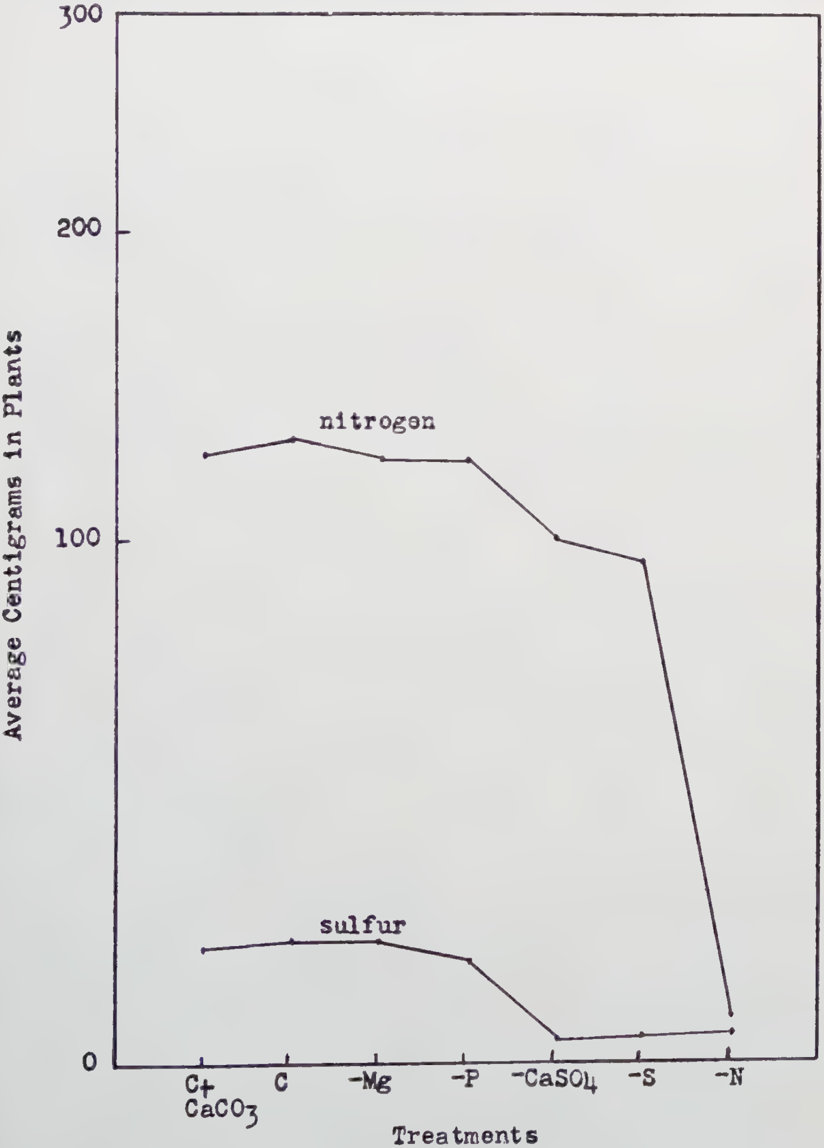

Figure 5.—Variation in Composition of Oats as Affected by Treatment.

A sulfur or nitrogen deficiency gave low percentages for these elements in the forage. A deficiency of nitrogen in the presence of a good supply of sulfur gave a high sulfur percentage, while a deficiency of sulfur in the presence of a good nitrogen supply gave a high nitrogen percentage. The nitrogen and sulfur percentage curves are reversed, that is, a shortage of one gives high values for the other. The centigrams of either nitrogen or sulfur in the harvested forage were low when there was a deficiency of either of these elements. Other variations in treatments had no great effect in that respect (Table 2 and Figure 5).

Results of Test with Lupines on Arredondo Loamy Fine Sand

The lupines grew well and the only difference that could be detected in them was that the ones without sulfur seemed slightly yellow.

Sulfur increased the yield of lupines (Table 3) about 20 percent. Neither $CaCO_3$, magnesium, nor phosphorus had any significant effect on yield. The results therefore, are quite similar to those for oats on the same soil.

Experiments with Blanton Fine Sand, Level Phase

This soil was obtained from the Suwannee Valley Station at Live Oak, Florida. It was taken from a weedy area where fertilizer had not been applied recently. The relatively available nutrients in pounds per acre were as follows:: CaO, 56; MgO, very low; P_2O_5, 18; K_2O, 22; and NO_3, very low. It had a pH value of 5.3. These results suggest a poor soil.

One lupine and two corn tests were conducted with this soil at the greenhouse.

Lupine Experiment on Blanton Fine Sand, Level Phase

Nine pounds of soil were used in each culture.

On the basis of two million pounds of soil to the acre the complete fertilizer treatment (Tables 4, 5, 6, and 7 list the treatments) consisted of the following in pounds per acre: calcium lactate, 600; nitrogen from NH_4O_3, 36; phosphorus from $Ca(H_2PO_4)_2.H_2O$, 120; potassium from KCl, 120; Mg $(C_2H_3O_2)_2.4H_2O$, 160; $CaSO_42H_2O$, 400; $CuCl_2.2H_2O$, 10; $ZnCl_2$, 10; $MnCl_2.4H_2O$, 10; H_3BO_3, 2; and $Na_2MoO_4.2H_2O$, 0.4. In the treatments where calcium or sulfur were not applied, potassium sulfate, magnesium sulfate and calcium lactate were substituted so as to elminate one or the other element as the case might be.

The 600 pounds per acre of calcium lactate was mixed uniformly with the soil. The other treatments were applied as follows: The top 2½ inches of soil were removed and the calcium sulfate applied at that level. Then ½ inch of soil was added and all water soluble nutrients applied in water solution. Another ½ inch of soil was added and the phosphate was applied. The remaining 1½ inches of soil were then put back into the container. Where calcium lactate was substituted for calcium sulfate it was applied the same as the calcium sulfate.

The treatments were replicated four times in randomized blocks, and the plants were grown outside on a platform. Any leachings from rain were returned to the containers from which they came.

White seeded sweet yellow lupines were planted December 14, 1954, but since the stand was irregular the plants were removed and seeded again December 30, 1954. The seed was innoculated. As soon as a stand was assured, the plants were thinned to 3 per container.

The lupines were harvested as flowering began on April 1, 1955. The soil was washed out of the roots, and the nodules picked off. Values for foliage, roots, and nodules were thus obtained.

TABLE 4.—EFFECT OF FERTILIZER TRATMENT ON MEAN DRY WEIGHT IN GRAMS OF LUPINES GROWN ON BLANTON FINE SAND, LEVEL PHASE.

Treatments	Foliage	Roots
Complete except minor elements	13.1	9.8
Complete	18.6	9.0
Complete except $CaSO_4$	12.1	8.5
Complete except Mo	10.7	7.1
Complete except Zn	18.0	8.4
Complete except Cu	17.2	7.0
Complete except Mn	17.6	8.0
Complete except B	15.5	7.8
Complete except Mg	10.6	6.0
Complete except P	17.6	8.2
Complete except K	8.3	5.2
Complete except N	16.9	7.4
Complete except Ca	21.1	9.1
Complete except S	13.8	9.1
L.S.D. at 5 percent	3.6	1.6
L.S.D. at 1 percent	4.8	2.1

TABLE 5.—EFFECT OF FERTILIZER TREATMENT ON MEAN DRY WEIGHT OF NODULES AND MEAN NITROGEN CONTENT OF NODULES IN PERCENTAGE AND WEIGHT.

Treatment	Weight Nodules, Grams	Percentage Nitrogen in Nodules	Milligrams Nitrogen in Nodules
1. Complete except minor elements	2.2	5.1	112
2. Complete	2.1	5.5	116
3. Complete except $CaSO_4$	1.2	4.0	48
4. Complete except Mo	2.1	4.4	92
5. Complete except Zn	2.1	5.7	120
6. Complete except Cu	2.0	5.4	108
7. Complete except Mn	2.1	5.5	116
8. Complete except B	2.1	5.5	116
9. Complete except Mg	1.8	4.3	77
10. Complete except P	2.0	5.6	112
11. Complete except K	1.1	4.6	51
12. Complete except N	2.2	5.1	112
13. Complete except Ca	2.1	5.5	116
14. Complete except S	1.3	4.0	52
L.S.D. at 5 percent	0.3	0.4	
L.S.D. at 1 percent	0.4	0.5	

Corn Experiments on Blanton Fine Sand, Level Phase

The treatments for the corn experiments were the same as for lupines except the calcium lactate in the complete treatment was 400 pounds per acre and ammonium nitrate 216 pounds of nitrogen per acre.

The amount of soil per container, and manner of applying fertilizer were the same as for lupines. The treatments were replicated four times in randomized blocks.

Two corn experiments were conducted—one outside the greenhouse and the other in the greenhouse.

In the outside experiment five Dixie 18 corn seed were planted in each pot on March 14, 1955, and thinned to three plants per pot as soon as a stand was assured.

The original amount of ammonium nitrate was applied to the pots again on April 20, 1955.

The corn was harvested when it was about two feet tall on April 26, 1955.

The inside corn was seeded with Dixie 18 corn on March 16, 1955 and thinned to 3 plants per container soon after it came up. This corn was harvested April 18, 1955, when it was about two feet tall.

Results of Lupine Experiment on Blanton Fine Sand, Level Phase

The lupines grew well except where a deficiency seemed to be critical. Where there was a deficiency of anything sufficient to markedly restrict growth the plants seemed slightly yellow. Where potash was not applied there seemed to be a rusty-like appearance of the lower leaves.

The yield of the foliage (Table 4) was significantly increased by minor elements, molybdenum, calcium sulfate, magnesium, potassium, sulfur (also in Figure 2), and very nearly by boron. Even though this soil is low in phosphorus and calcium the addition of these elements did not significantly affect the yield. The lack of response to calcium and phosphorous agrees with the results in the previous lupine test. The results for calcium sulfate were similar to those for sulfur indicating that the sulfur of the calcium sulfate was the effective element.

Beacuse of the difficulty of removing all soil, root yields may not be reliable, but the results (Table 4) suggest that the effects on root growth were similar to those on foliage. However, it appears that an application of sulfur had no effect on root yield. Copper had no effect on foliage yield, but appeared to increase root growth.

It is difficult to be certain about the number of nodules on lupines since they grow together and form clumps. Therefore, they were picked off the roots and weighed. Furthermore, the pink color inside the nodules seemed to vary. For that reason the nitrogen content of the nodules was determined and the weights and analyses are given in Table 5. The lack of calcium sulfate, sulfur, magnesium or potash decreased the weights of nodules. The nitrogen content was decreased by a lack of the same elements as well as by molybdenum deficiency. A sulfur or poatsh deficiency had a prounounced effect on the total amount of nitrogen in the nodules. There was considerable effect in that respect by a deficiency of magnesium or molybdenum.

The chemical composition and the amount of minerals in the lupines are given in Tables 6 and 7, and presented graphically in Figures 6 and 7. The percentage of nitrogen in the plants is decreased mainly by treat-

TABLE 6.—EFFECT OF FERTILIZER TREATMENT ON MEAN PERCENTAGE COMPOSITION ON OVEN-DRY BASIS OF ABOVE-GROUND PORTION OF LUPINES.

Treatment	Percentage Composition					
	S	N	P	K	Ca	Mg
1. Complete except minor elements	.71	3.0	.39	1.00	1.74	.25
2. Complete	.53	3.3	.29	.71	1.69	.20
3. Complete except $CaSO_4$	.10	2.9	.40	1.14	1.11	.26
4. Complete except Mo	.77	2.5	.36	1.00	1.91	.24
5. Complete except Zn	.67	3.7	.32	.75	1.85	.22
6. Complete except Cu	.67	3.1	.27	.72	1.77	.24
7. Complete except Mn	.67	3.3	.27	.82	1.76	.22
8. Complete except B	.72	3.4	.30	.91	1.78	.28
9. Complete except Mg	.84	2.3	.34	1.19	1.79	.14
10. Complete except P	.61	3.5	.23	.77	1.59	.23
11. Complete except K	1.02	3.0	.34	.34	2.69	.38
12. Complete except N	.64	3.3	.30	.97	1.79	.22
13. Complete except Ca	.52	3.2	.27	.71	.63	.26
14. Complete except S	.08	2.9	.33	1.16	1.24	.20
L.S.D. at 5 percent	.09	0.2	.05	.17	.19	.04
L.S.D. at 1 percent	.12	0.3	.07	.23	.26	.05

TABLE 7.—EFFECT OF FERTILIZER TREATMENT ON MEAN MILLIGRAMS OF MINERALS IN ABOVE-GROUND PORTION OF LUPINES.

Treatment	Milligrams of Minerals					
	S	N	P	K	Ca	Mg
1. Complete except minor elements	93	398	51	131	228	32
2. Complete	100	603	53	130	318	37
3. Complete except $CaSO_4$	12	352	49	137	133	32
4. Complete except Mo	79	275	38	102	201	25
5. Complete except Zn	119	664	58	134	332	40
6. Complete except Cu	115	539	46	125	305	41
7. Complete except Mn	118	578	48	144	311	40
8. Complete except B	110	528	46	139	276	43
9. Complete except Mg	89	248	36	126	192	15
10. Complete except P	107	618	40	137	280	41
11. Complete except K	84	248	27	28	219	31
12. Complete except N	108	554	50	162	302	38
13. Complete except Ca	109	678	56	149	133	55
14. Complete except S	11	392	45	159	170	28
L.S.D. at 5 percent	20	123	10	26	68	8
L.S.D. at 1 percent	26	165	13	34	92	11

ments which decrease yields such as molybdenum, magnesium, sulfur or potash deficiency. Since this is a legume, nitrogen in the fertilizer had no effect. The sulfur content, of course, was low where sulfur was not applied. It tended to be high where treatments decreased the yield—such as molybdenum, potash or magnesium deficiency. Calcium was relatively high with potash deficiency and low where calcium was not applied and where sulfur was deficient. Potassium was high where there were deficiencies of molybdenum, sulfur or magnesium. Of course, it was low where potassium was not applied. Where there were some variations for phosphorus and magnesium they were more nearly constant.

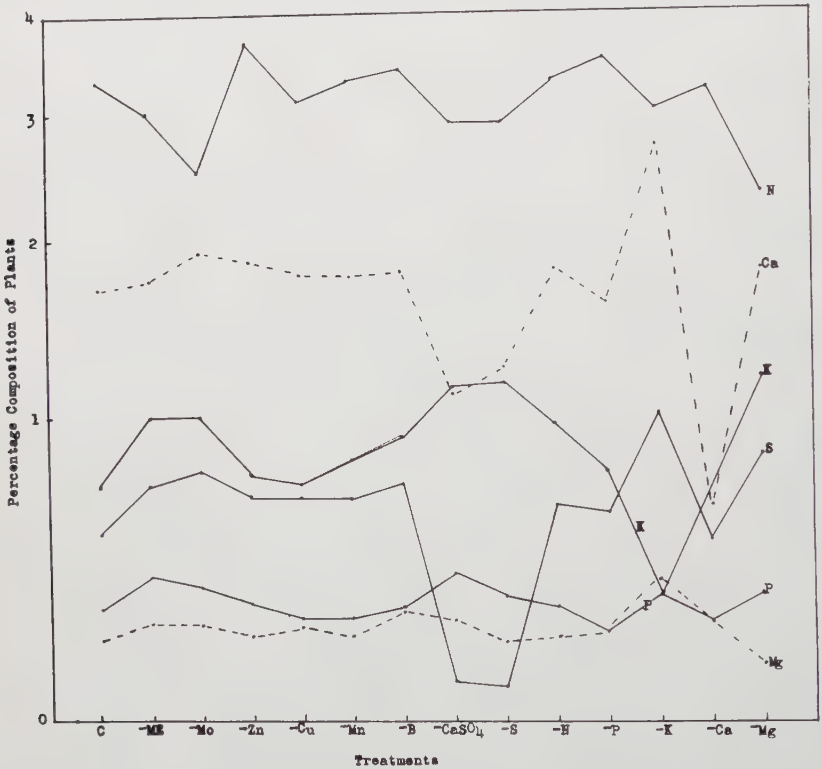

Figure 6.—Variation in Composition of Lupine as Affected by Treatment.

NOTE: C denotes complete treatment which includes all major and minor elements. —ME denotes treatment in which no minor elements were added.

A deficiency of any element often gave high percentage values, but the yield was low. It is, therefore, of interest to know how the total amount of the elements in the plants ranged. This relationship is shown in Figure 7. The amounts of phosphorus and magnesium in the plants are relatively uniform. To a lesser extent the same is true of potassium, although a deficiency of potassium resulted in a very low amount of potassium in the plants. Sulfur deficiency decreased the amount of sulfur in the plants while other deficiencies did not have too much effect. Treatments which lowered yields, in general decreased the total amount of

nitrogen and calcium in the plants. However, elimination of calcium from the treatment did not decrease lupine growth and yet the total amount of calcium in the plants was appreciably lower.

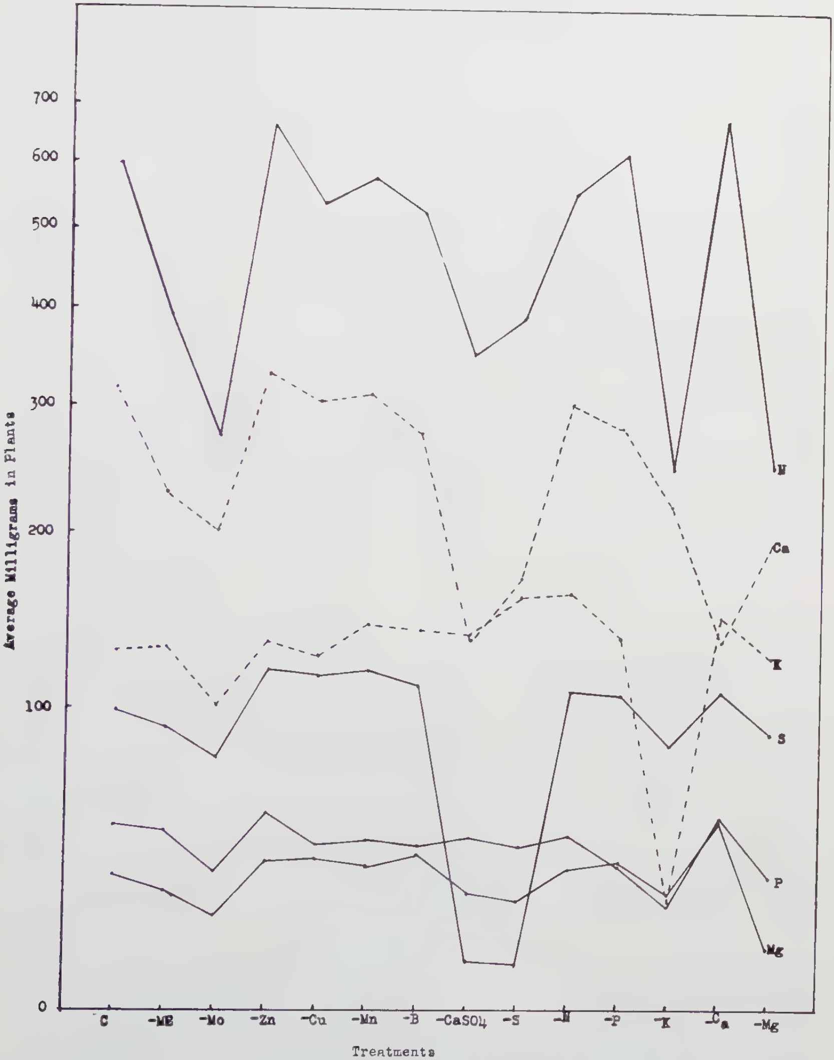

Figure 7.—Variation in Composition of Lupine as Affected by Treatment.

Results of Corn Experiment on Blanton Fine Sand, Level Phase

The corn grown both inside and outside the greenhouse grew very well. The inside corn grew a little faster and developed deficiency symptoms earlier, but so far as one could observe, the characteristics of the plants in both places were the same. However, the plants outside were grown longer before harvest, and were larger at that time.

Figure 8.—Zinc deficiency (white band) of Dixie 18 corn.

Figure 9.—One stage in sulfur deficiency of Dixie 18 corn.

Where phosphorus was not applied the plants were smaller and had considerable purple on the upper blades. Where zinc was not applied the corn exhibited zinc deficiency (Figure 8) which is commonly called white bud. The characteristics of white bud have been described(6). Nitrogen deficiency was characterized by small yellow plants. Without sulfur (Figure 9) the plants first developed stripes. The characteristics of sulfur deficiency in corn have been described(6). Without adequate potassium the margins of the lower blades became brown, and the plants seemed watery and many of them bent over near the ground level (Figure 10). The lower blades of plants grown without a magnesium application had purplish-red margins which changed to brown. Few stripes developed where magnesium was not applied and the plants were about as large as any up to harvest time.

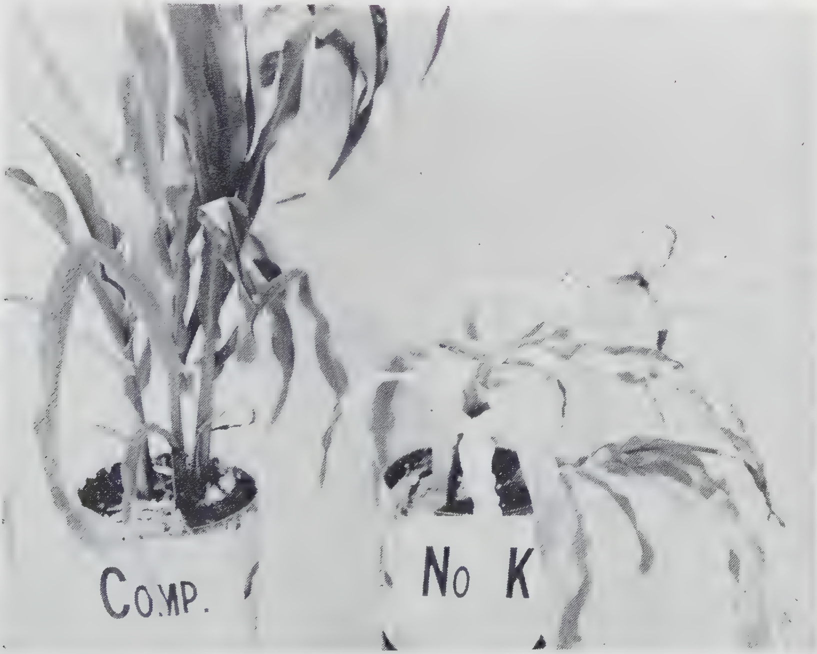

Figure 10.—Left, Dixie 18 corn with complete fertilization; right, the same except no potassium. Note the weak stalks of potassium defiicient plants and marginal browning of the lower blades.

The yields are given in Table 8. The minor elements, calcium sulfate, sulfur, zinc, phosphorus, potassium or nitrogen greatly increased the yield of corn both when grown inside and outside the greenhouse. It was postulated that there might be a difference in response to some of the treatments under the two conditions of growth. The only indication of this was the effect of boron, calcium and copper. Boron significantly decreased growth on the outside, while calcium significantly decreased growth on the inside. Copper significantly increased growth on the inside.

The same three elements had a numerical effect in the same direction in the other cases, but the differences were not statistically significant.

TABLE 8.—Effect of Fertilizer Treatment on Mean Dry Weight in Grams of Corn Grown Inside and Outside the Greenhouse.

Treatment	Grams Foliage	
	Outside	Inside
1. Complete except minor elements	15.6	11.4
2. Complete	21.0	17.4
3. Complete except $CaSO_4$	6.8	6.4
4. Complete except Mo	20.6	16.3
5. Complete except Zn	11.3	8.4
6. Complete except Cn	20.7	13.8
7. Complete except Mn	21.4	16.4
8. Complete except B	23.2	17.9
9. Complete except Mg	20.9	16.3
10. Complete except P	3.6	3.9
11. Complete except K	4.6	5.7
12. Complete except N	0.7	1.4
13. Complete except Ca	22.1	21.3
14. Complete except S	7.4	6.0
L.S.D. at 5 percent	1.3	1.7
L.S.D. at 1 percent	1.7	2.3

The chemical composition of the corn is given in Table 9 and the amount of the elements in the corn is indicated in Table 10. Possibly, the differences can better be shown by graphs so they were prepared. The graphs for the corn grown inside and outside the greenhouse were relatively similar. For that reason, only the inside results are presented in Figures 11 and 12. Any element left out of the fertilizer treatment tended to decrease the persentage of that element in the plant. The nitrogen percentage was markedly increased by minor elements, zinc, calcium sulfate, sulfur, potassium or phosphorus deficiency. The percentage potassium in the plant was similarly affected by the same deficiencies. The calcium content of the corn was relatively constant, except where calcium or sulfur was not in the fertilizer, in which cases calcium was low. Phosphorus or potassium deficiency tended to slightly increase the calcium content. The curves for phosphorus, magnesium and sulfur show differences in percentage composition due to treatments, but the differences are not as striking as for the other three elements.

The total mount of any element in a plant was decreased when that element was not in the fertilizer treatment. The lack of calcium sulfate, sulfur, potassium or phosphorus decreased the total amount of nitrogen in the plants. The total amount of potassium in the plant was relatively constant except it was very low when potassium was not in the fertilizer. Such deficiencies as minor elements, zinc, calcium sulfate, sulfur, potassium or phosphorus decreased the total amount of calcium in the plant. The curves for phosphorus, magnesium and sulfur show some differences for treatment but the differences are not as striking as in the case of the other curves.

TABLE 9.—Effect of Fertilizer Treatment on Mean Percentage Composition of Corn Foliage When Grown Inside and Outside the Greenhouse.

Treatment	Percent S in Plants		Percent N in Plants		Percent P in Plants		Percent K in Plants		Percent Ca in Plants		Percent Mg in Plants	
	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside
1. Complete except minor elements	.19	.21	2.9	2.2	.24	.38	1.04	1.53	.60	.63	.27	.38
2. Complete	.16	.16	2.5	1.4	.18	.21	.56	.85	.64	.51	.25	.24
3. Complete except $CaSO_4$	.08	.07	4.5	3.3	.23	.32	1.69	2.75	.50	.32	.30	.29
4. Complete except Mo	.15	.15	2.5	1.5	.19	.18	.56	.95	.65	.56	.25	.26
5. Complete except Zn	.26	.26	4.1	2.8	.39	.47	1.23	2.16	.71	.62	.40	.38
6. Complete except Cu	.17	.17	2.6	1.9	.20	.20	.54	1.29	.62	.50	.25	.25
7. Complete except Mn	.15	.17	2.1	1.6	.17	.17	.50	1.08	.66	.52	.22	.25
8. Complete except B	.14	.16	2.3	1.4	.20	.20	.58	1.00	.58	.51	.22	.24
9. Complete except Mg	.14	.15	2.3	1.7	.17	.19	.52	1.06	.68	.59	.13	.13
10. Complete except P	.28	.29	4.3	3.6	.14	.12	2.82	3.60	.53	.64	.26	.29
11. Complete except K	.46	.31	5.1	3.8	.52	.40	.39	.33	.96	.70	.68	.54
12. Complete except N			1.1	0.9								
13. Complete except Ca	.20	.21	2.2	1.5	.16	.20	.47	.83	.39	.27	.23	.24
14. Complete except S	.06	.06	4.5	3.0	.24	.27	1.99	2.59	.50	.30	.29	.24
L.S.D. at 5 percent	.04	.03	0.4	0.1	.05	.04	.16	.24	.08	.06	.04	.04
L.S.D. at 1 percent	.06	.04	0.5	0.2	.06	.06	.21	.32	.11	.08	.05	.05

TABLE 10.—Effect of Fertilizer Treatment on Mean Milligrams of Minerals in Foliage of Corn When Grown Inside and Outside the Greenhouse.

Treatment	Mgs.* S in Plants		Mgs. N in Plants		Mgs. P in Plants		Mgs. K in Plants		Mgs. Ca in Plants		Mgs. Mg in Plants	
	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside
1. Complete except minor elements	30	24	447	245	39	43	161	174	94	73	42	43
2. Complete	33	29	517	248	36	36	117	148	135	89	52	42
3. Complete except $CaSO_4$	5	5	303	207	16	20	115	174	33	20	21	18
4. Complete except Mo	30	25	511	242	40	29	115	155	134	91	52	43
5. Complete except Zn	29	22	451	234	44	39	136	180	80	52	45	32
6. Complete except Cu	35	24	538	255	43	28	113	170	130	69	51	34
7. Complete except Mn	31	28	453	265	36	27	107	176	142	86	48	41
8. Complete except B	34	29	524	244	45	36	135	179	135	90	51	43
9. Complete except Mg	30	25	479	277	36	28	110	173	142	96	27	21
10. Complete except P	10	11	152	141	5	5	100	140	19	25	10	12
11. Complete except K	21	18	232	217	24	23	18	19	44	40	31	31
12. Complete except N			8	14								
13. Complete except Ca	44	45	494	311	37	44	103	176	86	57	50	52
14. Complete except S	5	4	330	183	18	16	71	156	36	18	22	15
L.S.D. at 5 percent	4	4	54	26	6	7	17	19	12	11	6	6
L.S.D. at 1 percent	5	5	72	34	8	10	23	26	16	15	8	8

* Mgs. = Milligrams.

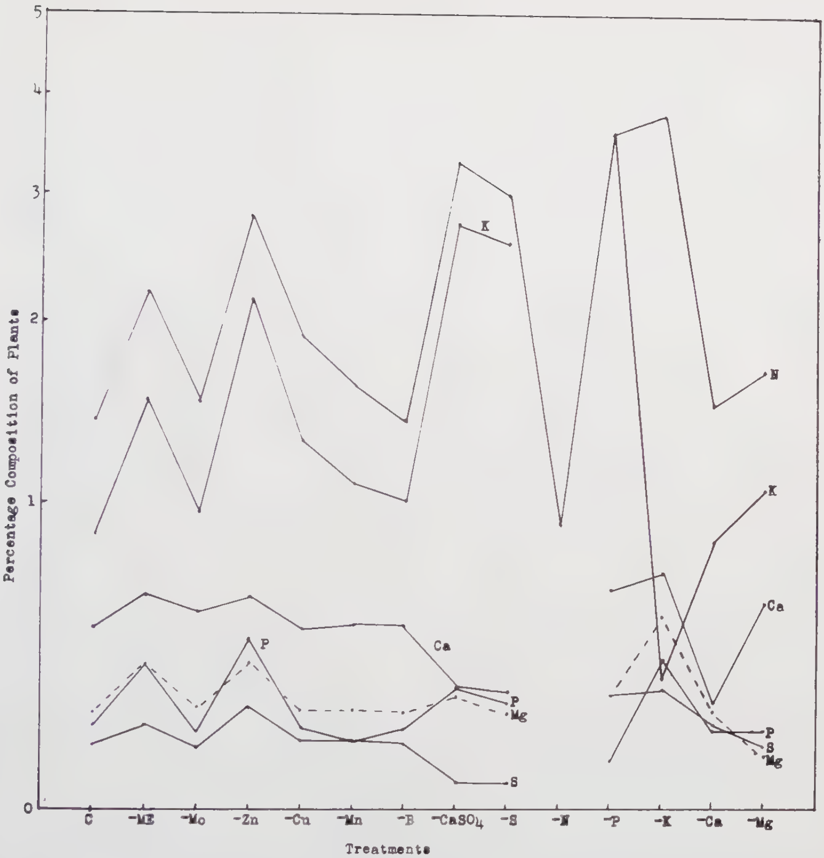

Figure 11.—Effect of Treatment on Composition of Corn Grown in Greenhouse.

Summary and Conclusions

Oats and lupines were grown on Arredondo loamy fine sand and lupines and corn were grown on Blanton fine sand, level phase. The experiments were conducted at the greenhouse with a complete fertilizer treatment and with incomplete treatments. Yields were obtained and analyses of the plant material made. From the results the following conclusions may be drawn.

Sulfur and nitrogen had a pronounced effect on the yield of oats grown on Arredondo loamy fine sand. Sulfur also increased the yields of lupine on that soil. The yellow color of oats due to sulfur deficiency was corrected in ten days by an application of magnesium sulfate.

Phosphorus and lime had no apparent effect even though no field fertilizer treatments had been applied to this Arredondo loamy fine sand since 1930.

There was an inverse effect on the chemical composition of the oats when treated with sulfur and nitrogen. That is, nitrogen decreased the

percentage of sulfur in the foliage while sulfur decreased the nitrogen content. That appears to be related to difference in growth.

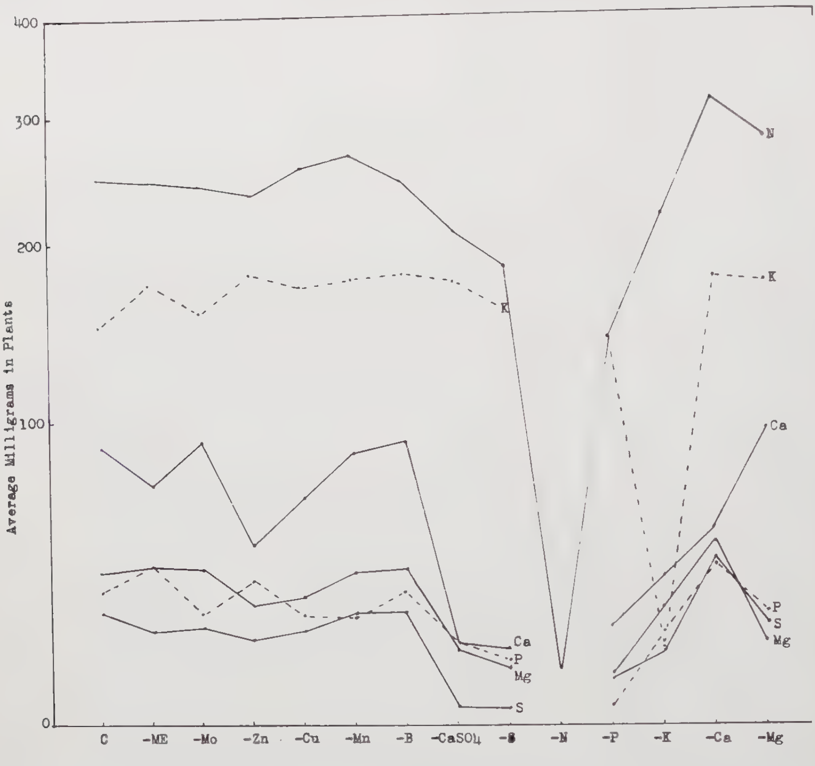

Figure 12.—Effect of Treatment on Composition of Corn Grown in Greenhouse. Note: C denotes complete treatment which includes all major and minor elements. —ME denotes treatment in which no minor elements were added.

When lupines were grown on Blanton fine sand, level phase, molybdenum, magnesium, potassium and sulfur markedly increased vegetative yields, while boron had a moderate effect. Even though this soil was low in available nutrients, phosphorus and calcium had no noticeable effect on vegetative yields.

The weights of the nodules on the lupines were increased by sulfur, magnesium and potassium while the percentage of nitrogen in the nodules was increased by molybdenum, magnesium, potassium and sulfur.

Corn on Blanton fine sand, level phase, grew much alike in the greenhouse and on a platform outside of the greenhouse.

Zinc, sulfur, phosphorus, potassium and nitrogen treatments had a marked effect on forage yields of corn.

The effects of molybdenum, zinc, phosphorus and boron treatments on the forage yields of lupines were not the same for corn even though the two crops were grown on the same soil in as nearly the same manner as possible.

The yield of neither crop was materially affected by calcium treatment even though the soil was low in available calcium.

In general an application of an element, except nitrogen on lupines, tended to increase the percentage composition of that element in the plant.

Deficiencies resulting in unbalanced nutritional conditions considerably changed the chemical composition of the plants. For example, a zinc deficiency for corn almost doubled the percentage of nitrogen in the foliage.

In general, the variation in percentage composition was greatest for nitrogen and potassium.

The total amount of an element in the forage tended to be somewhat constant for treatments which did not materially affect the yield, while the opposite seemed to be true for treatments that caused large yield differences.

Undoubtedly many factors influence the composition of a plant, but the results indicate that unbalanced nutritional conditions, such as are likely to occur in Florida, materially affect the chemical composition of plants. Since the quality of plant material is a reflection of chemical composition, the results are of special significance for our state.

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Soil Testing and Fertilizer Ratios in North Florida

Frank E. Boyd*

The thirty-four counties (North and West of Flagler, Alachua, and Dixie) comprising the North Florida fertilizer consuming area are made up of the well-drained uplands and terrace lands of the Red and Yellow soil order. The soils are mainly sandy loams and sands with some clay and sandy hammocks. The natural vegetative growth is mainly pines with some hardwoods and wiregrass. The soil colors vary from gray to yellow to brown to red or combinations of these colors. All these soils are within the acid pH range and, therefore, need liming for maximum yields of most crops.

Since these soils do not differ greatly from the soils across South Georgia and South Alabama and since plant root systems do not respect county borders, state boundaries or other imaginary lines in their search for the proper ratio of the essential plant food elements, we venture to suggest for North Florida the same ratio-grade program being promoted in the adjoining states.

Down through the years the Land Grant College of Florida through its Experiment Station System has been field testing all available fertilizer materials in all possible combinations and at single, double, and triple rates to determine the correct ratios of Nitrogen (N), Phosphate (P), and Potash (K) for the principal crops and soil areas of the state. The information collected from these thousands of field tests conducted in cooperation with leading farmers, by the mobile units, at the several sub-stations, and at the Main Station (Gainesville) suggests the practical need for only three basic fertilizer ratios and matching grades for North Florida, namely,

Varying nitrogen with equal P-K as in 8-8-8, 3-9-9, (4-12-12), and 0-12-12
Varying nitrogen with high P-low K as in 4-7-5, (4-16-8), and 0-16-8
Varying nitrogen with low P-high K as in 4-6-8, (4-8-16), and 0-10-20

There are low, medium, and high grades available. Higher multiples, like 0-14-14 or 0-20-20 instead of 0-12-12, may be used. Low nitrogen goods should get extra nitrogen before or after planting for most crops. The grades in parentheses ( ) are set apart to show the proper relationship between the three groups as pointed out later.

North Florida soils are generally low in organic matter (source of soil nitrogen), therefore, for all practical purposes the total nitrogen requirement of all crops must be supplied largely through legumes, manures, and commercial sources.

World renowned scientists have pointed out to us that N-P-K, to share co-equally in normal plant production, must be taken up in the ratio $5N - 1P_2O_5 - 1.7\ K_2O$, or five times as much nitrogen as phosphate and about three times as much nitrogen as potash, for maximum growth and yield.

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TABLE 1.—RATIO-GRADE GROUPS SOLD IN NORTH FLORIDA—1954-55. FROM DEPARTMENT OF AGRICULTURE FERTILIZER CONSUMPTION STATISTICS.

Varying N Even P — K Grades	Tons	Varying N High P — Low K Grades	Tons	Varying N Low P — High K Grades	Tons
0-10-10	78	0-10-8	49	0-8-24	28
0-12-12	2,524	0-14-10	3,255	0-8-25	141
Average OPK	Total	0-16-8	446	0-10-20	808
0-12-12	2,602	Average OPK	Total	0-12-20	681
2-10-10	485	0-14-10	3,750	0-14-20	1,205
2-12-12	5,672	2-10-4	55	Average OPK	Total
2-14-14	1,008	2-14-10	18	0-12-20	2,863
3-8-8	7,218	3-8-3	233	2-10-20	99
3-9-9	7,171	3-8-5	169	2-12-20	21
3-10-10	705	3-12-10	1,123	3-6-8	11
3-12-12	1,159	3-14-10	35	3-8-9	35
3-14-14	261	4-6-4	7	3-8-10	28
4-5-5	78	3-6-5	46	3-9-12	7
4-6-6	143	4-7-5	18,896	4-5-7	81
4-8-8	8,906	4-8-4	3,088	4-6-8	1,120
4-9-9	14	4-8-5	71	4-8-10	85
4-10-10	92	4-8-6	15,827	5-3-6	134
4-12-12	12,613	4-9-6	61	5-5-6	212
5-5-5	25	4-9-7	169	5-5-8	553
5-10-10	1,206	4-10-6	21	5-6-8	89
6-6-6	242	4-10-7	50,955	5-6-10	14
6-7-7	4,756	4-12-6	35	5-8-20	56
6-8-8	14,912	5-7-5	4,958	5-8-25	32
6-12-12	784	5-8-3	1	6-4-6	176
7-9-9	2,893	5-8-5	578	6-4-8	489
8-4-4	21	5-9-3	32	6-5-6	7
8-6-6	7	5-9-5	1,519	6-6-8	242
8-8-8	5,693	5-10-5	181	6-7-8	465
8-12-12	134	5-10-8	26	6-8-10	1
8-16-16	14	6-8-4	1,951	7-5-7	107
9-5-5	131	6-8-6	2,253	8-4-6	92
9-6-6	867	6-8-7	3,802	8-4-8	56
9-9-9	1,476	6-9-6	734	8-6-8	32
10-8-8	14	6-9-7	1,223	10-4-10	655
10-10-10	314	6-10-4	161	10-5-10	4
Average NPK	Total	Average NPK	Total	Average NPK	Total
5-9-9	79,035	4-9-6	109,238	6-5-8	4,903
4 Leading Grades	45%	4 Leading Grades	80%	4 Leading Grades	45%
0-12-12	2,524	0-14-10	3,255	0-14-20	1,205
3-9-9	7,171	4-10-7	50,955	4-6-8	1,120
4-12-12	12,613	4-7-5	18,896	6-4-8	489
6-8-8	14,912	4-8-6	15,827	10-4-10	655
33 Grades	81,637	33 Grades	111,988	33 Grades	7,766
Per Cent of Total	41		56		3
Actual Needs					
*Statewide %	73		19		8
*North Florida %	70		25		5
Alabama %	74		8		17
Georgia %	74		18		8

* From Soil Testing Laboratory data.

Due to the relatively high requirement of many crops for nitrogen and to varying rates and methods of application, it is not always convenient nor desirable to apply the total needs of this element in mixed goods, so "varying nitrogen" is suggested as a part of the general ratio pattern set forth above. All the nitrogen (N) does not team up directly with the P and K since it may be applied before, at time of, or after planting, or in a combination of these methods to better fit in with farm management practices. Certainly, the use of nitrogen necessitates varying procedures.

The nitrogen percentages in the ratio groups listed in Table 1 are quite variable, fluctuating widely from zero upward, while P and K needs are more stable and easier to establish and maintain. It is suggested, therefore, that we begin the program of unification by first setting up simple 1-1, 2-1, and 1-2 P-K ratios.

The mineral plant food content (phosphate and potash and other essentials) of North Florida soils is quite variable and is generally inadequate to produce desired yields. All Florida crop soils need help from fertilizer to insure profitable production. The type research information outlined above was obtained from field tests located at relatively few points, therefore, such findings permit only *general fertilizer recommendations* for a given field and crop. While the needs of an individual farm will most certainly fall in one or the other of the above basic ratio-grade groups, the question is, which one? Modern day farmers are demanding a *specific recommendation*, yes, a *prescription* for each field and crop. *Only a soil test can answer this question.*

The soil test is a new tool designed to measure the available mineral elements (P and K) in the soil in terms of low-medium-high supply and to match such phosphate and potash with a suitable fertilizer grade to give the growing crop balanced plant food. To properly interpret and apply the soil test findings, the results must be coordinated with field research data accumulated over the years from soils of similar character. Only technically trained personnel familiar with background research can do this job properly.

Since the growing crop will draw its total plant food from the soil and from added fertilizer, the two sources must be so combined that the soil and fertilizer together gives the crop a balance of the primary (P and K) mineral elements. This means that for those soils "high" in phosphate and "low" in potash, we would apply a fertilizer "low" in phosphate and "high" in potash (like 4-8-16 or 0-10-20) to give the crop equal phosphate and potash or a balanced ration. Other situations involve low-high P-K and even P-K.

To further simply such a procedure, let us illustrate with three grades (4-12-12, 4-16-8, and 4-8-16) by showing that if we mix one ton of 4-16-8 with one ton of 4-8-16, we have two tons of 4-12-12. A similar set of ratio-grades would satisfy most crops grown in North Florida. At least there is some rhyme and reason for the use of such ratio-grades.

To satisfy actual farm needs for fertilizer based on field and soil tests, industry would need to manufacture and store just three basic P-K ratios with only 2 to 4 grades per group. This is another case of simplification of a problem that is almost out of hand in those states with unlimited registration of grades.

In general the fertilizer industry is following the basic ratio pattern very well, but is greatly overdoing the number of grades per ratio group. Industry, through its dealers and other outlets, is not now supplying the farmer the correct tonnage in each ratio group according to soil test findings. For a comparison of soil needs vs. fertilizers sold, see Table 1.

Please note tonnage by ratio-grade groups actually sold and percentage of total for each group (41-56-3). For comparison study the next two lines which show actual needs according to soil tests. North Florida figures are only slightly different from state-wide precentages. Another comparison of interest involves Alabama, Georgia, and Florida.

Making up the total tonnage of North Florida are 99 grades (33 in each ratio-grade group). It has been suggested that grades carrying odd numbers (3-5-7-9 etc.) be eliminated thus reducing the grade list by 43 per cent. Still another reduction could be made by setting up an "approved" list from which the Soil Testing Laboratory would make all recommendations. Some states are following this procedure. The problem ahead is to adjust the fertilizer tonnage by ratio-grade groups to the needs of our soils and crops.

Soil Management Problems in Florida*

F. B. Smith **

A distinguishing characteristic of the soils of Florida is the tendency to extremes in certain properties. These soils tend to be unusually light or very heavy in texture but seldom ever intermediate. That is, the texture is either a sand or a clay, but rarely ever a loam or silt loam. Nearly all sands contain some clay but the amount of clay is usually very low. Another tendency to exremes is in the mineral and organic constituents. The mineral soils are usually very low in organic matter, whereas the organic soils may be very low in mineral matter. Since the mineral soils are low in both clay and organic matter, they have a low exchange capacity and are poorly buffered. This characteristic of these soils necessitates a number of special problems in their management not common to other regions.

In general, the soils of Florida are inherently poor in the plant food nutrients, yet some of the soils are very rich in certain constituents. For example, the well to moderately well drained members of the Central Florida uplands, such as the Arredondo, Gainesville and Hernando series, may contain up to ten times as much phosphorus as the average fertile soil in the United States. The very poorly drained organic soils, such as Everglades, Istokpoga and Loxahatchee peats are extremely high in total nitrogen. All of these soils are low in potassium and some of the minor elements. The management of these soils bears a close relation to these properties and characterizes the region as quite varied in different areas.

RUNOFF AND EROSION CONTROL

Runoff and accelerated erosion are of minor importance in the Florida Peninsula because of the nearly level to gently sloping topography and sand texture. Some erosion may occur on the more rolling areas of the well to moderately well drained Central Florida uplands where depth to clay is less than 30 inches. Vegetative cover and contour cultivation are recommended on the steeper slopes. Leaching losses may be serious on the well to moderately well drained Lakeland, Jonesville, Hernando, Gainesville, Blanton, Kanapaha, Rex and Fellowship sands and loamy sands. These soils occur extensively in the Ceneral Florida uplands and are widely used for the production of general field crops such as corn, peanuts, bright tobacco, watermelons and pasture. Where climatic conditions permit they are also used for citrus and truck crops. Liming to pH 5.5 to 6.0 and growing of winter cover crops for grazing and green manure crops are recommended. Leaching losses on the poorly drained soils are not as serious as might be expected, especially if the acid soils are limed.

Soil Management, as commonly used, refers to the preparation and treatment of soils for the production of crops. By treatment is meant "any practice required for the economic, sustained production of crops." The term is incorrectly used by many to include the broader term "land management."

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Severe wind erosion occurs on some of the well drained sands during the winter and spring months when these soils are bare. Severe damage to young crops by blowing sand is frequent over large areas, This damage is greatly reduced by growing strips of cover crops, such as lupine, across the field at frequent intervals at right angle to the direction of the prevailing winds or by the use of windbreaks.

DRAINAGE

One of the most important characteristics of the soils of Florida on the basis of use management is their natural drainage condition. Six broad groups are recognized, ranging from the excessively drained deep sands through the poorly and very poorly drained soils to marsh and swamp where surface water stands throughout the year.

The removal of excess surface water from the somewhat poorly drained Ona, Scranton, Leon, Immokalee and similar soils may easily be accomplished by planting on ridges or beds with shallow ditches at intervals of 20 to 30 rows, or at less frequent intervals in pastures. Large drainage ditches are required on the poorly to very poorly drained Bladen, Arzell, and similar soils. Drainage canals and drainage ditches fitted with dams and pumps may be necessary, especially in the very poorly drained organic soils area where removal of excess surface water quickly is required, or to check the rate of removal or reverse the flow of water. Water control is emphasized and caution should be observed to prevent "over drainage."

IRRIGATION

The soils of the Central Florida uplands are well to moderately well drained and where the depth to clay exceeds 42 inches they are droughty. The water requirement of certain crops grown during the winter and spring months exceeds the amount available in rainfall at that season of the year. Hence, supplemental irrigation is often necessary and is a common practice, especially for high acre value crops.

Vegetables grown during the fall, winter and spring months, which usually constitutes the dry season, are the principal crops grown under irrigation, even when grown on the somewhat poorly drained Ona, Immokalee and Leon soils. Celery is grown extensively on Leon soils under a system of sub-irrigation in the Sanford area. Citrus on the well to moderately well drained Lakeland, Eustis and Orlando, and bright tobacco on the Jonesville, Chiefland, Blanton and Hernando soils are frequently grown under suplemental irrigation.

DEVELOPMENT AND MAINTENANCE OF SOIL FERTILITY

Liming. Most of the soils of Florida are acid in reaction, except the marls and rockland of the Everglades and adjacent flatwoods along the east and west coasts that are underlain with calcareous sand, clay, marl, or limestone. These latter soils represented by Ruskin, Broward, Dade, Cocoa, Bradenton, Sunniland, Keri, Copeland and Parkwood series are neutral to alkaline in reaction. The Arredondo, Gainesville, Fellowship, Hernando, and Ft. Meade series have a relatively high base status and are usually only slightly acid in reaction. A summary of soils tested

during the period 1944 to 1954 showed that 40 percent of the soils tested were pH 5.5 or below and that 14 percent were strongly acid, pH below 5.0.

Because of the extremely low buffer capacity of the soils, lime is applied with caution to prevent over-liming injury. Such injury has been associated with heavy applications of lime in the past on citrus, potatoes and tobacco. Consequently, there has been a tendency to avoid the use of lime and some soils have become strongly acid. The use of lime on acid soils has increased markedly in recent years.

Certain long-continued practices to control insects and disease may accumulate toxic residues or produce other unfavorable conditions in the soil. For example, sulfur from sulfur sprays on citrus returns to the soil where it is readily oxidized to sulfate and on the well drained Lakeland, Eustis and similar soils; this is leached together with calcium to produce soil acidity. The treatment of the soil with sulfur to control disease of potatoes produces strong acidity of the soil. The somewhat poorly and the poorly drained Bladen, Leon, and associated soils are used extensively in potato production. These soils are naturally strongly acid. Where it is necessary to use this treatment repeatedly these soils frequently become too acid for nitrification. Such soils require lime to bring the soil reaction back to pH 5.2 to 5.5 which will give good control of scab and yet permit fairly rapid nitrification. The strongly acid flatwoods soils such as Leon, Plummer and Portsmouth, have a low phosphorus-fixing power and unless limed, phosphate is lost readily by leaching. On the other hand, lime increases the availability of phosphote in the soils of high sesquioxide content. Toxic concentrations of copper have accumulated from the use of copper sprays and heavy applications of copper sulfate in fertilizers. Lime reduces this toxicity.

Fertilization. The most widely recognized need of the soils of Florida, and the most common soil management practice is that of fertilization. There were 1,203,949 tons of mixed fertilizers consumed in Florida during the fiscal year July 1, 1955 to June 30, 1956. The soils are inherently poor in the fertility constituents but the production of good crops is possible through the liberal use of commercial fertilizer. The bulk of fertilizer used consists of the complete NPK mixtures. However, a large tonnage of minor elements is consumed annually in the production of citrus and vegetable crops. Magnesium, manganese, zinc and copper in the fertilizer or as a nutritional spray are standard recommendations for citrus.[1] Manganese, zinc, copper and boron are used extensively in the fertilizer on organic soils. Certain crops respond to one or more of the minor elements and the need for minor elements may be more widespread than is recognized at present, but a crop response to the minor elements has not been obtained on all soils. The use of all minor elements on all soils for all crops is not recommended because of needless expense and also the possibility of building up toxic concentration.

Generally, the crops heavily fertilized are grown out of season and command high prices, or are high acre vlaue crops. The cost of the heavy applications of fertilizer is of minor importance under such conditions and consequently heavy applications of fertilizers are made to fruit and vegetable crops. The long-continued use of fertilizers at extremely high rates of application produces certain management problems.

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[1] Florida Agr. Exp. Sta. Bul. 536, 1954.

For example, phosphorus accumulates in certain soil types and after a period of fertilization at high rates of application, with fertilizers of a 1-2-1 or 1-3-1 ratio, the phosphorus content of these soils builds up to three or four times the amount found in the average fertile soil. Such soils when first brought into cultivation require different fertilization than after they have been under cultivation for extended periods. The X-O-X type mixture, fertilizers containing no phosphate, may then be used. Because of high acidity and rapid leaching, accumulation of toxic concentrations of fertilizer salts are not widespread. However, on soils of restricted drainage, fertilization at high rates of application has resulted in such high concentration of soluble salts as to interefer with proper crop nutrition.

In spite of the fact that the highest per-acre rate of fertilizer use in the United States is in Florida there are many general field crops inadequately fertilized. For example, the yields of corn, peanuts, cotton, small grains and forage crops could be increased several fold by increasing the use of proper fertilizer on these crops.

Cropping Systems. Regular crop rotations are not generally practiced in Florida and there is some justification for continuous cropping under certain conditions, but the importance of a definite cropping system for sustained ,economic crop production is emphasized. Corn in Florida is generally laid-by in time for growth of a good crop of native legumes, weeds and grass. A winter cover crop to be plowed under or oats for grazing may be planted in the fall. The land is then available for corn again the following year. Continuous corn in this instance is essentially a three-year rotation as practiced farther north. Peanuts are often grown continuously on the same land but yields soon decline under this system. Experiments on Red Bay fine sandy loam have shown that peanuts grown in two and three year rotations maintained their initial yields. Corn yields on this soil type were generally higher in the two and three year rotations than when grown continuously. Certain crops, such as watermelons and tobacco are not grown continuously on the same land because of disease, but there is frequently little, if any, attention given to a systematic rotation of such crops. In the vegetable producing areas, two and three crops may be grown on the same land during the fall and spring. In most instances where one or more crops have been grown in the fall or spring a cover of grass or legume could and should be grown in the summer to be plowed under as a green manure in the preparation for a fall crop. New and improved cropping systems are urgently needed and are just as important to economic crop production as any other soil management practice. Cropping systems adapted to "horse and buggy" farming will not suffice for power farming where large cash outlays for machinery, fertilizers and chemicals are required. Conditions in Florida *are* different from those in other states and often conditions in one type of farming area within the state may be vastly different from those in another type of farming area.

SUMMARY

The soil management problems of the State, in general, are similar to those for soils of other states, but because of climatic conditions, crop requirements, and certain differences in soil characteristics, some of these

problems are of less importance here than elsewhere. On the other hand, problems of minor importance in other areas are most important in this area. The extreme in soil properties, coupled with the growing of crops out of season, especially in the lower peninsula, combine to make soil management more complex and relatively more important in the production of crops here than in other regions. Fairly good yields of crops may be obtained in other areas with relatively less attention to soil management than is possible in Florida.

The Effect of Various Soil Treatments on the Manganese Content of Cigar-Wrapper Tobacco Leaves*

B. D. Hurley, W. L. Pritchett, and H. L. Breland **

INTRODUCTION

Cigar-wrapper tobacco production in Florida is confined to relatively small areas, primarily in Gadsden and Madison counties. However, the approximately 4,000 acres of cigar-wrapper tobacco have a high value per acre which makes this crop one of the principal cash crops in the state. The high cost of production of this shade-grown crop has been estimated to be as high as $2,000 per acre. Some farmers have found that the prevalence of spots and other defects in the tobacco leaf, often attributed to unfavorable soil conditions, often results in low-quality and economic losses or relatively small profits.

Cigar-wrapper tobacco is generally grown on well-drained, relatively heavy fine sandy loams. Large quantities of the primary plant nutrients are usually applied to these soils to insure maximum plant growth; however, little attention has been given to the minor element status or to the balance of nutrients in the soil. One of the minor elements which has given some indication of affecting the quality of cigar-wrapper tobacco in other areas is manganese(2). Tobacco plants high in manganese had yellowish, non-elastic leaves, which were inferior in quality and burned to a "brick- or muddy-colored" ash(1).

Although manganese is commonly considered as being deficient in many Florida soils, it has been found to be present in rather large amounts in some of the heavier mineral soils of the state(4,5). Fiskel(4) reported that the exchangeable and easily reducible forms of soil manganese in West Florida soils are more than ample for crop production. Soil manganese is often classified into three groups: (a) exchangeable,[1] (b) easily reducible [2] and (c) total. Although the plant is believed to be capable of absorbing manganese only in the reduced form(7), there are a number of factors which affect the availability of this element in the soil. A reduction in soil reaction below pH 6.0, changes in the oxidation-reduction status of the soil(6) and additions of organic matter to increase biological activity(5) may influence the availability of soil manganese.

A preliminary survey of the manganese content was made in the spring of 1955 for a number of fields considered representative of the principal soil types used in the production of cigar-wrapper tobacco in

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[1] Manganese extracted with 1 N calcium nitrate.

[2] Manganese extracted with 1 N calcium nitrate and 0.2% hydro quinone.

Florida. The results of these analyses are given in Table 1. These soils generally contained more total manganese than reported for soils growing cigar-wrapper tobacco elsewhere(8).

An experiment was established in 1955 at the North Florida Experiment Station to investigate the nutrient requirements of cigar-wrapper tobacco. The data reported herein relate to the effect of certain soil treatments on the manganese content of the tobacco leaves.

METHODS

A 2^7 factorial (half-replicate) experiment with Dixie Shade cigar-wrapper tobacco was established March 25, 1955 on a well-drained Ruston-Orangeburg fine sandy loam. The manganese content of the soils in the experimental area was lower than most of the soils included in the survey (Table 1). The total manganese content of the plots ranged from 120 to 180 pounds per acre in the surface layer. The easily reducible and exchangeable manganese contents ranged from 76 to 102 and 6.6 to 9.6 pounds per acre, respectively. Each of the 64 plots consisted of four rows 32 feet long and 4 feet wide. All plots were shaded with double layers of cotton cloth about 8 feet above the soil surface. The experimental area had received a uniform broadcast application of manure at the rate of 16 tons per acre about two months before transplanting.

The soil treatments were as follows:

1. Two rates of calcium were 0 and 900 pounds per acre of CaO, broadcast as calcium hydroxide.
2. Two levels of magnesium were 0 and 300 pounds per acre of MgO, applied in the form of magnesium sulfate.
3. Potassium sulfate was applied in the rows at rates of 150 and 275 pounds per acre of K_2O.
4. Three levels of inorganic nitrogen (100, 175 and 250 pounds per acre of N) were applied in the rows as ammonium nitrate. Cottonseed meal served as the source of organic nitrogen and was applied at the rate of 175 pounds per acre of N.
5. Triple superphosphate was applied in the rows at rates of 90, 165 and 240 pounds per acre of P_2O_5 while the organic source—steamed bone meal—was applied at the rate of 165 pounds per acre of P_2O_5.

The tobacco from the experimental plots was harvested (primed) seven times at weekly intervals beginning May 25, 1955. However, only the leaves from the first, fourth and seventh primings were used in this study. Approximately three leaves were harvested at each priming, and the three primings included in this study represented the bottom, middle, and top leaves. The leaves were primed, cured, fermented, baled and stored according to generally acceptable methods.

About 40 leaves were selected at random to represent each plot for each priming. The midribs were removed and the remaining portions of the leaves were ground in a Wiley mill. One-gram samples were ashed in a muffle furnace for three hours at 450 to 500° C. The ash from each sample was dissolved in 20 ml. of 5 N HCl and brought to dryness.

TABLE 1.—THE CONTENT OF THE EXCHANGEABLE, EASILY REDUCIBLE AND TOTAL MANGANESE AND EXTRACTABLE NUTRIENTS IN SOME SOILS OF THE CIGAR-WRAPPER TOBACCO AREA.

Soil Type	pH	Expressed in Pounds per Acre						
		Manganese			Extractable*			
		Ex-change-able	Easily Re-ducible	Total	CaO	MgO	K_2O	P_2O_5
Orangeburg Fine Sandy Loam	5.65	5	115	276	256	155	377	80
	......	1	120	300	......	......	......	....
Ruston Fine Sandy Loam	5.60	10	86	220	624	176	432	100
	5.65	9	76	180	624	184	377	95
	5.70	3	125	280	344	147	371	32
	5.80	7	84	160	462	217	422	31
	5.85	10	102	120	462	176	377	59
Carnegie Fine Sandy Loam	5.35	2	96	330	444	300	336	13
Tifton Fine Sandy Loam	5.01	4	220	530	192	120	455	30
	5.22	11	240	22	274	167	371	89
Greenville Fine Sandy Loam	4.60	10	140	......	417	184	415	86
	5.54	1	232	......	434	269	360	15
	5.72	2	220	......	468	240	628	17
Norfolk Fine Sandy Loam	......	2	128	210	......	......	......	......
	......	1	80	180	......	......	......	......
	5.49	2	134	220	465	186	463	20

* Extracted with acid (pH 4.8) ammonium acetate.

Distilled water and 10 ml. of concentrated phosphoric acid (85%) were added to each sample and boiled. After the solutions were allowed to cool, 20 ml. of distilled water and 0.3 grams of potassium meta-periodate were added. The samples were placed on the hot plate for 30 minutes at 95° C to develop the permanganate color. These samples were diluted to 100 ml. and the manganese was determined on a colorimeter using a 525 millimicron wave length.

RESULTS AND DISCUSSION

The average contents of manganese in the tobacco leaves from plots receiving the various soil treatments are given in Table 2. It should be pointed out that the values represent the average of leaves from all plots receiving a particular treatment as compared to the average of all plots that did not receive this treatment. For example, 32 plots were unlimed while an equal number received lime equivalent to 900 pounds per acre of CaO.

Calcium: The calcium treatment highly significantly decreased the concentrations of manganese in the tobacco leaves as shown from statis-

tical analysis of these data in Table 3. This decrease in manganese absorption was closely related to the increase in soil pH from 5.4 to 5.9 in plots receiving calcium. It was also noted that the manganese content increased in the later primings (upper leaves); this was related to a general decline in soil reaction as the season progressed.

The interaction of calcium and potassium treatments on the manganese content of the leaves was statistically significant. This means that at the low level of soil calcium, the high rate of potassium increased the manganese concentration, while in plots receiving additional lime, the manganese uptake was decreased by the high rate of potassium.

The calcium-nitrogen interaction significantly influenced the manganese content in the leaves. The manganese concentrations in the leaves were increased with increasing rates of nitrogen, regardless of the liming rates. At the low level of calcium, for example, the 100, 175 and 250 pounds per acre rates of inorganic nitrogen resulted in manganese values of 72, 83, and 109 ppm respectively. This increase in manganese may have been due to reduction in soil reaction as a result of the acid-forming properties of ammonium nitrate.

The effect of the interaction between calcium and phosphorus in the soil on the concentrations of manganese in the leaves was highly significant. At the low level of soil calcium, the increasing rates of phosphorus (90, 165 and 240 pounds of P_2O_5 per acre) resulted in manganese concentrations in tobacco leaves of 87, 83 and 99 ppm, respectively. On the limed plots, the manganese concentrations increased directly with the rate of applied phosphorus. An explanation of this intereaction probably involves increased soil microbial activity, as well as plant growth, with the high rates of phosphorus.

Magnesium: The addition of magnesium sulfate significantly decreased the manganese content in the tobacco leaves (Table 3) in spite of the fact that there was a slight decrease in soil pH on plots receiving this treatment. The competition between magnesium and manganese for absorption may have been a factor.

The soil magnesium-nitrogen interaction significantly affected the manganese concentrations in the tobacco leaves while high rates of inorganic nitrogen increased the uptake of manganese; this effect was more pronounced in plots receiving no magnesium than in plots receiving the magnesium. This could have been due to the acid-forming properties of ammonium nitrate.

Potassium: The effect of the application of potassium sulfate on the manganese content in the leaves was not statistically significant. However, the manganese concentrations in the leaves increased with heavier applications of potassium in two of the three primings (Table 2).

On the other hand, the interaction between the potassium and nitrogen treatments resulted in a significant decrease in the manganese concentrations in the leaves. With increasing rates of potassium at each nitrogen rate, except at the 250-pound rate, the manganese content of the leaves was decreased.

The effect of the potassium-phosphorus interaction on the concentrations of manganese in the leaves was significant (Table 3). When the application of potassium sulfate was increased, with each level of phosphorus except at the middle rate (165 pounds per acre of P_2O_5), the

manganese concentrations in the leaves increased. When the middle rate of triple superphosphate was used, increasing the potassium sulfate decreased the manganese content.

TABLE 2.—THE MANGANESE CONTENT OF CIGAR-WRAPPER TOBACCO LEAVES FOR THREE PRIMINGS AS AFFECTED BY SOIL TREATMENTS.

Soil Treatments		Primings		
Kind	Lbs./Acre	1	4	7
		ppm of Mn		
	0	143	184	183
Calcium	900 CaO	103	131	147
Magnesium	0	120	170	171
	300 MgO	126	145	159
Potassium	150 K_2O	129	148	160
	275 K_2O	114	167	170
	100 N (Inorganic)	114	129	146
Nitrogen	175 N (Inorganic)	125	158	161
	250 N (Inorganic)	131	201	199
	175 N (Organic)	122	141	153
	90 P_2O_5 (Inorganic)	119	160	168
Phosphorus	165 P_2O_5 (Inorganic)	124	154	164
	240 P_2O_5 (Inorganic)	138	183	177
	165 P_2O_5 (Organic)	110	132	151

Nitrogen: The increasing rates of ammonium nitrate significantly increased the manganese concentrations in the tobacco leaves (Tables 2 and 3). As the nitrogen rates increased, the manganese concentrations increased, indicating a linear function. But the increase in manganese was greater between the 175- and 250-pound rates than between the 100- and 175-pound rates, thus giving the nitrogen effect a highly significant quadratic function (Table 3).

The application of inorganic nitrogen increased the manganese content in the leaves more than did the organic nitrogen (Table 2). This may have been due to the fact that ammonium nitrate is more acid-forming than cottonseed meal when applied at equivalent rates of nitrogen.

Phosphorus: The effects of phosphorus treatments on the manganese concentrations in cigar-wrapper tobacco leaves were highly significant (Table 3). The sources of phosphorus did not significantly differ in their effect on the absorption of manganese according to statistical analysis. However, the average manganese contents for the organic phosphorus treatment were lower than those average manganese values for the inorganic phosphorus treatment which received the equivalent rate of P_2O_5.

In comparing the three levels of inorganic phosphorus, the two lower levels gave about the same manganese content in the tobacco leaves, but the higher level of phosphorus gave a higher manganese content (Table 2).

Therefore, the statistical analysis showed that increasing rates of inorganic phosphorus had a highly significant linear and quadratic function.

The nitrogen-phosphorus interaction significantly increased the manganese in tobacco leaves (Table 3). At the 250-pound rate of inorganic nitrogen, the 240-pound rate of inorganic phosphorus increased the absorption of manganese more than any other level of phosphorus, while at the same rate of nitrogen, the 90-pound rate of inorganic phosphorus increased the absorption of manganese more than the 165-pound rate of either organic or inorganic phosphorus. At this high level of nitrogen, there was little difference in manganese absorption between phosphorus sources.

TABLE 3.—Analysis of Variance Showing the Effect of Soil Treatments on the Concentration of Manganese in Cigar-Wrapper Tobacco Leaves.

Source	D.F.		M.S.	F.
Levels of calcium		1	87,680.26	67.32**
Levels of magnesium		1	5,622.51	4.32*
Levels of potassium		1	1,592.76	N.S.
Levels of nitrogen		3	61,041.74	46.87**
Organic vs. Inorganic	1		68,139.01	52.32**
Linear function	1		6,105.13	4.69*
Quadratic function	1		108,881.07	83.61**
Levels of phosphorus		3	29,998.89	23.04**
Organic vs. Inorganic	1		112.55	N.S.
Linear function	1		19,900.13	15.28**
Quadratic function	1		69,984.00	53.74**
Calcium x Potassium		1	5,974.17	4.59*
Calcium x Nitrogen		1	7,943.88	6.10*
Magnesium x Nitrogen		1	5,841.05	4.49*
Potassium x Nitrogen		1	6,267.76	4.81*
Calcium x Phosphorus		1	9,732.76	7.43**
Potassium x Phosphorus		1	7,663.38	5.88*
Nitrogen x Phosphorus		1	8,334.51	6.40*
Error		65	1,302.25	

N.S. Not significant at the 5% level of probability.
* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

At the 175-pound rate of inorganic nitrogen there was essentially no difference in the absorption of manganese as the inorganic phosphorus was increased from 165 pounds to 240 pounds of P_2O_5 per acre. However, at the low rate of phosphorus, a decrease in the absorption of manganese was noted. The 165-pound rate of organic phosphorus resulted in lower manganese concentrations in the leaves than any of the inorganic phosphorus treatments.

At the low level of applied nitrogen, the 165-pound rate of inorganic phosphorus increased the concentrations of manganese in the leaves over that for the 90- and 240-pound rates of phosphorus.

With the use of organic nitrogen, the concentrations of manganese in the leaves increased as the rates of inorganic phosphorus were increased.

The manganese concentrations in the leaves increased with increasing rates of inorganic nitrogen at the 90- and 240-pound rates of phosphorus. However, at the 165-pound rate of inorganic phosphorus, the manganese concentrations in the leaves were decreased. Regardless of the source and rate of phosphorus, ammonium nitrate was more effective in increasing the manganese concentrations in the leaves than organic nitrogen.

The manganese concentration was generally higher in the top leaves than in the lower leaves, regardless of soil treatment. It has been reported(3) that the availability of manganese increases as temperature increases.

SUMMARY

Manganese has been reported to adversely affect the quality of cigar-wrapper tobacco when absorbed in large amounts. The concentrations of total manganese in the soils of the cigar-wrapper tobacco-producing areas of Florida are often higher than in other areas. However, since the availability of manganese is affected by a number of factors, such as reaction, oxidation-reduction potential, organic matter and activity of the soil organisms, it was deemed desirable to determine the level of manganese in the cigar-wrapper tobacco of Florida and to determine whether certain soil treatments might prove effective in reducing the absorption of this element.

Applications of calcium hydroxide increased the soil pH and decreased the concentration of manganese in the leaves. This may have been due to competition between calcium and manganese for absorption, as well as a result of the reduction in the availability of soil manganese at higher pH levels.

Soil application of magnesium decreased the manganese content of the leaves. However, since magnesium was applied as a neutral salt which had little effect on the soil reaction, this reduction in manganese absorption was probably due to competition between the two cations.

There were indications that soil applications of potassium sulfate enhanced the plant uptake of manganese, but the effect was not clear-cut.

Increasing soil applications of nitrogen as ammonium nitrate increased the concentrations of manganese in the tobacco leaves. Nitrogen added as cottonseed meal did not increase the uptake of manganese as much as an equivalent amount of nitrogen as ammonium nitrate. This was probably due to the acid-forming properties of ammonium nitrate as compared with cottonseed meal.

Increasing rates of phosphorus as triple superphosphate enhanced the absorption of manganese by the plant. Phosphorus in steamed bone meal did not increase the concentration of manganese in the leaves as much as an equivalent quantity of phosphorus from triple superphosphate.

Soil treatments involving low calcium and magnesium in combination with inorganic nitrogen and phosphorus resulted in abnormally high concentrations of manganese in the tobacco leaves. These values, found to be as high as 600 ppm manganese in the top leaves, exceeded concentrations reported to result in poor quality cigar-wrapper tobacco in other areas(1).

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The Relationship of Leaf Position (Priming) to Yield and Composition of Cigar-Wrapper Tobacco

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INTRODUCTION

Cigar-wrapper tobacco is one of the most important cash crops in southwest Georgia and northwest Florida. In 1956, it comprised a total of about 5,100 acres, of which the Florida area represented about 4,000 acres, chiefly in Gadsden County. The gross farm value of the crop in 1955 was over $9,000,000 for Florida alone.

Since quality is so important in cigar-wrapper production and since a considerable loss of income has been experienced by some growers due to certain quality defects, a study was initiated to determine the effects of soil treatments on these quality factors. The study included various fertility levels applied to Ruston and Orangeburg fine sandy loam soils at the North Florida Experiment Station at Quincy.

As the choicest leaves are usually found between the fourth and twelfth positions on the plant (middle primings), it was thought desirable to determine the variation in yield by primage, some of the quality factors, and the chemical composition of the tobacco. This paper deals only with these aspects of the project.

EXPERIMENTAL PROCEDURE

The plots (16 x 32 feet, with 8-foot alleys) were measured off and marked. This allowed four rows of tobacco to be grown four feet apart, with only the two center rows being harvested for record.

All plots received a uniform application of manure in January, 1955, at the rate of 16 tons per acre, cut in with a disc harrow. The calcium and magnesium treatments were applied broadcast on March 2 and also cut in with the disc harrow. The area was then bedded to the middles by using a one-horse turning plow, making four furrows to each row. The fertilizer materials were weighed out separately for each plot, applied in the drill, and mixed with the soil before bedding back on the row.

The Dixie Shade variety of cigar-wrapper tobacco was used because it has blackshank resistance comparable to Rg. It also has considerable root-knot resistance, better leaf type and certain other advantages(9).

The tobacco was set in the field on March 25 and the first priming made on May 25, 61 days after the plants were set. The tobacco was primed seven times at about five-day intervals. The number of leaves removed, or harvested, at each priming varied from two to four per plant,

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depending on the ripeness of the leaves. The leaves were laid down immediately in numbered canvas baskets pulled ahead of the primers to eliminate handling as much as possible.

The lowest two or three marketable leaves, which are comparatively small and generally sandy, are called "sand leaves." The next 14 to 16 leaves are called "middles." The last two or three leaves primed are called "tops." The green leaves range in length from an acceptable minimum of 15 inches for sand leaves (16 inches for tops) to as much as 26 inches. The width of the leaves is usually about 60 per cent of their length(8).

All plots were primed on the same day. The leaves were then strung, fastened to laths and hung in the barn for curing. The tobacco was essentially air-cured but gas heaters were also used for supplemental heating as neeeded. After curing, the tobacco was removed from the barn, sweated in bulk, and afterward weighed for yield.

METHODS

Samples from each plot and each priming were graded according to color (lightness and uniformity), thickness and soundness, and certain defects. Two hands of the tobacco were taken at random from each plot and each priming for chemical analysis. The midribs were removed and the leaves ground in a Wiley mill.

The total nitrogen was determined by the standard Kjeldahl method. Calcium, magnesium, phosphorus, potassium and manganese were determined by dry-ashing a suitable sample at 450°C, then making to volume in 0.1 N HCl. Phosphorus was determined by the ammonium molybdate-stannous chloride method. A Bausch and Lomb colorimeter was used for determining the intensity of the color developed. The manganese was determined colorimetrically using potassium meta-periodate.

A portion of the solution was then passed through a sufficient quantity of Dowex 1-X8 anion exchange resin to remove the anions known to interfere with certain cation determinations(7). Calcium and potassium were then determined on the Beckman Model B spectrophotometer with an acetylene-oxygen flame attachment. Magnesium was determined on a Beckman Model D U spectrophotometer with photomultiplier and hydrogen-oxygen flame attachment.

The easily exchangeable calcium and magnesium in the soil were removed by leaching with ammonium acetate (pH 4.8), using a soil solution ratio of 1 to 5, and then determined on the Beckman Model B spectrophotometer with acetylene-oxygen flame attachment.

The fire-holding capacity, or "burn test," was determined by igniting the cured and sweated tobacco leaves with a red-hot electric filament and measuring the length of time the leaves held fire.

The ash color, or per cent reflectance, was determined after ashing by using a diffuse reflectance attachment on the Beckman Model B spectrophotometer. The plant samples were ashed in open crucibles over Bunsen burners. The ash was then ground with a mortar and pestle to assure uniformity and the per cent reflectance determined at a wave length of 800 mu.

RESULTS AND DISCUSSION

The average yield of the 64 plots, considered as 64 replications for the present study, is given for each priming in Figure 1. It will be noted that in this particular crop, the fourth and fifth primings were larger than the other primings, although this is not typical of crops in general.

The yield remained almost constant for the first three primings and then increased from 195 to 229 pounds per acre in the five days from the third to the fourth priming. The yield continued to increase to a high of 252 pounds per acre for the fifth priming and then decreased sharply for the sixth and seventh primings.

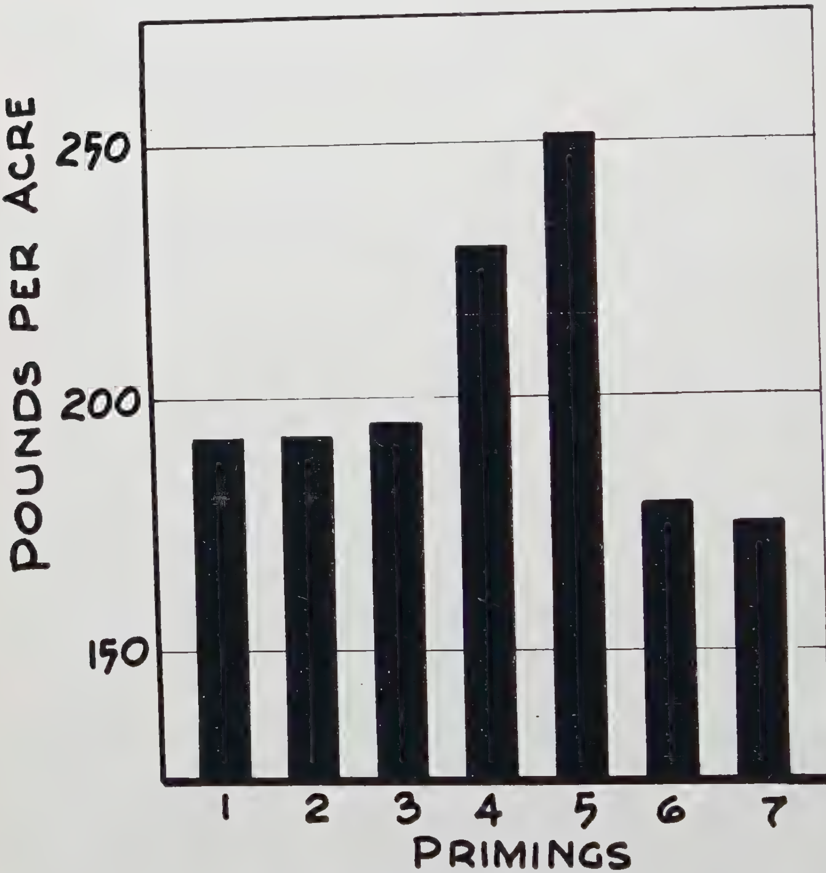

Figure 1. The average yield of cigar-wrapper tobacco obtained from 64 plots by primings.

The grade indices were calculated by applying to the grade data a scale of comparative values beginning with 1.0 for the best grade (Light Wrapper) and decreasing for the inferior grades. This gives a weighted value showing the grade quality. The higher the grade index, the better

the quality of the tobacco. The different grades and the relative values used in calculating the grade indices are given in Table 1.

TABLE 1.—THE DIFFERENT GRADES AND THE RELATIVE VALUES USED IN CALCULATING THE GRADE INDICES.

Grade	Relative Value
Light Wrapper	1.0
Off Color	0.9
Light Medium	0.7
Dark Wrapper	0.4
No. 2 Off Color	0.6
Spotted	0.5
Bleeding Vein	0.5
Black Tip	0.0
Light No. 2	0.6
Light Broke	0.3
Tender	0.0
Filler	0.0

Figure 2. The average grade index of cigar-wrapper tobacco for each priming.

The grade indices, by primings, are given in Fgure 2. The first priming had a grade index of 0.371, but it decreased to 0.270 for the second priming. Even though the yield remained about constant for the first and second primings, the quality of the tobacco was not as good for the second priming. The quality of the tobacco was much better for the third priming, having a grade index of 0.512, but the yield still remained about the same. The fourth and fifth primings produced the highest yields and also the highest grade indices. The yields for the last two primings were below that of the first three, but the grade indices decreased only to 0.569. A grade index of 0.550 or above is generally considered good.

The addition of 900 pounds of CaO per acre as hydrated lime, raised the available calcium in the soil after about two and one-half months (Figure 3). When the plants started growing vigorously, about the time of the first priming, the calcium content of the leaves and the available calcium in the soil decreased rapidly until after the third priming. There was a subsequent increase in the calcium content of the leaf after the third priming, although the soil calcium did not increase again until after the crop was removed (Figure 3).

Garner(3) found that the actual requirements of the plant for calcium appear to be somewhat less than those for potassium, but under average conditions the content of calcium in the leaf exceeds that of potassium because of the more abundant supply. This was not found to be true for this particular crop. Actually, the calcium content of the leaf was only about one-half that of the potassium.

The first priming, consisting largely of sand leaves, did not contain as much potassium as the second priming (Figure 4). After the second priming, the potassium content tended to decrease with each priming through the sixth and then increased slightly for the seventh. The increase may have been due to the light rains received on June 17 and 18 since seasons having ample moisture usually produce leaves containing a higher potassium content than dry seasons.

The decrease in available potassium in the soil coincides very closely with the decreased potassium content of the leaves for each priming. This occurred in spite of the fact that the soil contained an average of 381 pounds of available K_2O per acre (as shown by soil tests) and the addition of an average of 212 pounds of K_2O per acre from fertilizer. The optimum application for the general area has been considered to be about 200 pounds of K_2O per acre(10) and this is the amount generally applied by growers. It has also been reported that mild potassium deficiency symptoms may be apparent with as much as 2.5 per cent of potassium present in the affected tissues(3). Therefore, if the potassium content of the leaf is to be maintained at a higher level, it will apparently be necessary to make a larger initial potassium application, to apply a potassium side-dressing, or both.

The average magnesium and phosphorus contents of the tobacco leaves appear to be about the same, regardless of position on the plant. The maximum variation is 33.3 and 21.7 per cent for phosphorus and magnesium, respectively. Nevertheless ,an analysis of variance indicated that the variations from one priming to the other were highly significant. The two curves coincide rather closely, although the magnesium content was approximately five times that of the phosphorus (Figure 5). Magnesium appears to be well distributed throughout the plant. It is the only metal

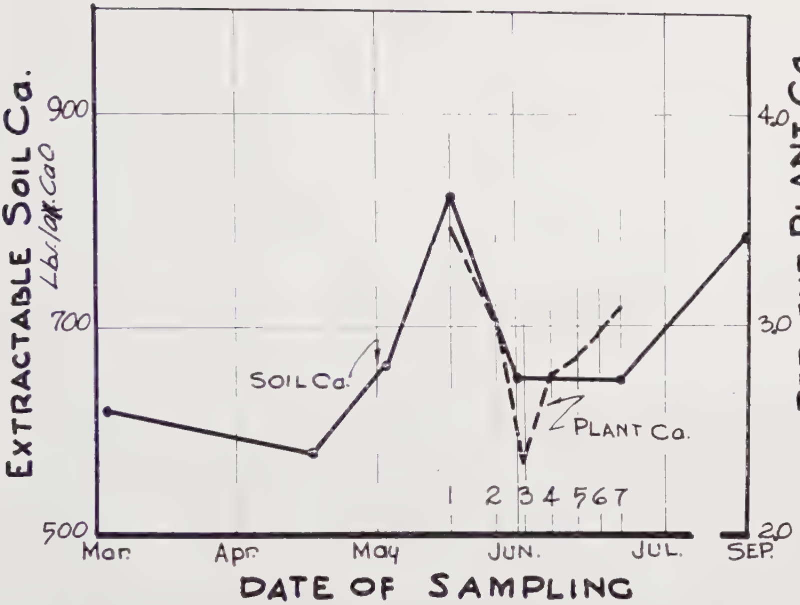

Figure 3. The total calcium content of cigar-wrapper tobacco leaves by primings and the easily exchangeable calcium found in the soil at different dates.

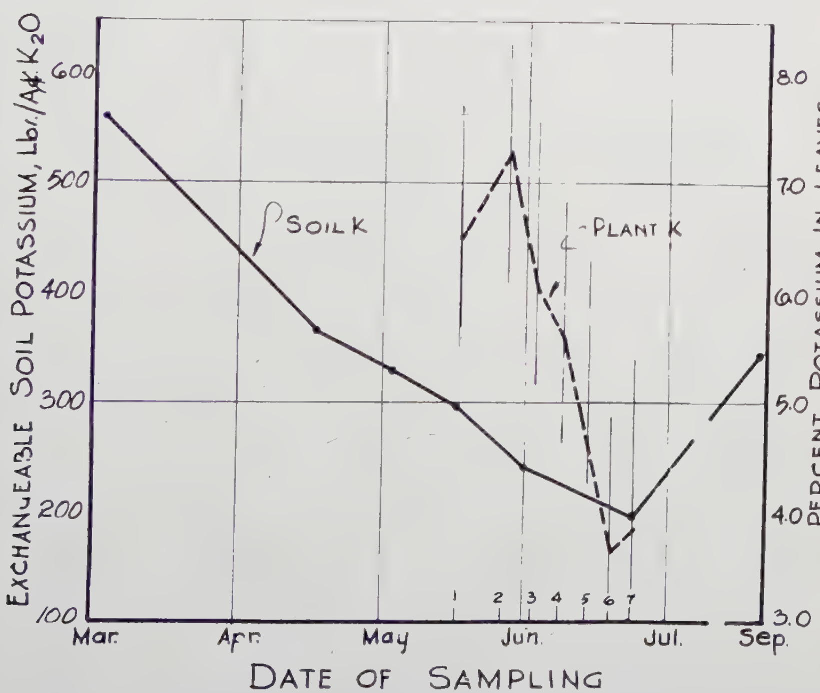

Figure 4. The total potassium content of cigar-wrapper tobacco leaves by primings and the easily exchangeable potassium found in the soil at different dates.

TABLE 2.—Analyses of Variance of the Relationship of Leaf Position (Primings) on the Yield and Quality of Cigar-Wrapper Tobacco.

Source	D. F.	M. S.	F Value
Yield			
Primings	6	50,996.917	67.03 **
Replications	63	816.414	1.07 N.S.
Error	378	760.792	
Grade Index			
Primings	6	1.689	76.80 **
Replications	63	0.022	1.00 N.S.
Error	378	0.022	
Ash color			
Primings	6	2,445.935	98.59 **
Replications	63	51.226	2.06 **
Error	378	24.810	
Burn Test			
Primings	6	2,857.561	434.35 **
Replications	63	14.573	2.22 **
Error	378	6.579	

** Significant at the 1% level of probability.

TABLE 3.—Analyses of Variance of the Relationship of Leaf Position (Primings) on the Chemical Composition of Cigar-Wrapper Tobacco.

Source	D. F.	M. S.	F Value
Calcium			
Primings	6	6.837	122.35 **
Replications	63	0.214	3.83 **
Error	378	0.056	
Magnesium			
Primings	6	0.517	17.51 **
Replications	63	0.126	4.25 **
Error	378	0.030	
Phosphorus			
Primings	6	0.032	26.97 **
Replications	63	0.002	1.52 *
Error	378	0.001	
Potasium			
Primings	6	123.667	1,098.72 **
Replications	63	0.322	2.86 **
Error	378	0.113	
Nitrogen			
Primings	6	38.844	785.34 **
Replications	63	0.144	2.84 **
Error	378	0.051	
Manganese			
Primings	6	20,960.606	18.31 **
Replications	63	19,159.989	16.74 **
Error	378	1,144.476	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

entering into the composition of green chlorophyll, of which it constitutes somewhat less than two per cent. Phosphorus, on the other hand, has been found to hasten growth and promote proper ripening of the crop(5).

The average nitrogen and maganese contents of the tobacco produced very similar curves. Both tended to increase with each priming with only a few exceptions (Figure 6). Nitrogen is always concentrated in the more rapidly growing plant parts and appears to be translocated from older to younger parts of the plant, particularly if the nitrogen supply is restricted. It is of outstanding importance, not only in its effects on the growth of tobacco, but also in its influence on various elements of quality in the cured leaf, as has been demonstrated by Garner *et al.*(4) and other workers.

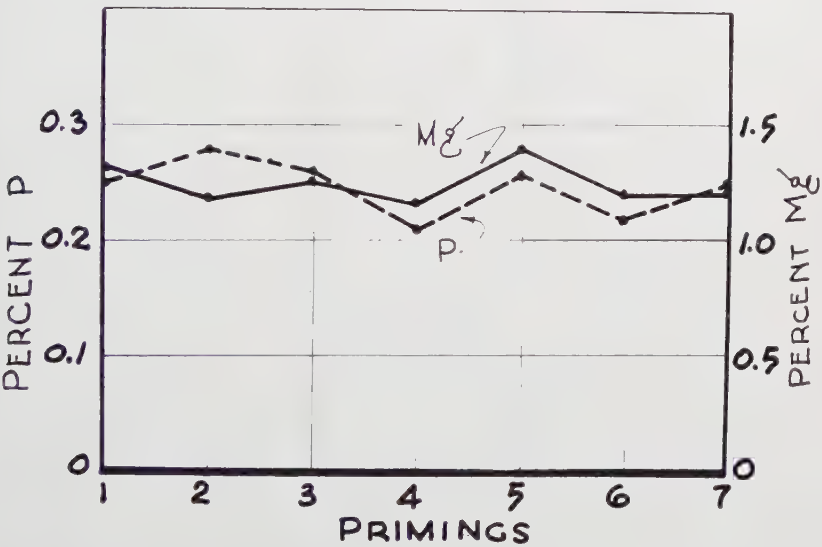

Figure 5. The total magnesium and phosphorus found in cigar-wrapper tobacco by primings.

The fire-holding capacity, or "burn test", shows that the first three primings produced the best burn (Figure 7). There were four burn tests of only 7.0 second or less. In each case, the plots received 300 pounds of MgO per acre from magnesium sulfate, but no calcium. There were eighteen burn tests of 8.0 seconds or below, all but one of which received magnesium and only four of which received the calcium application.

Sixteen samples of the 64 plots had an average burn test of 10.0 seconds or longer for the average of all seven primings. In each case no additional magnesium was applied to the soil. Eleven out of the 16 plots received 900 pounds of CaO per acre as hydrated lime.

It has been found by many investigators (1, 2, 6) that potassium has a decidedly beneficial effect upon the burn or combustion of tobacco. The generally accepted theory is that as the potash content increases, it causes a corresponding increase in fire-holding capacity. Since the time

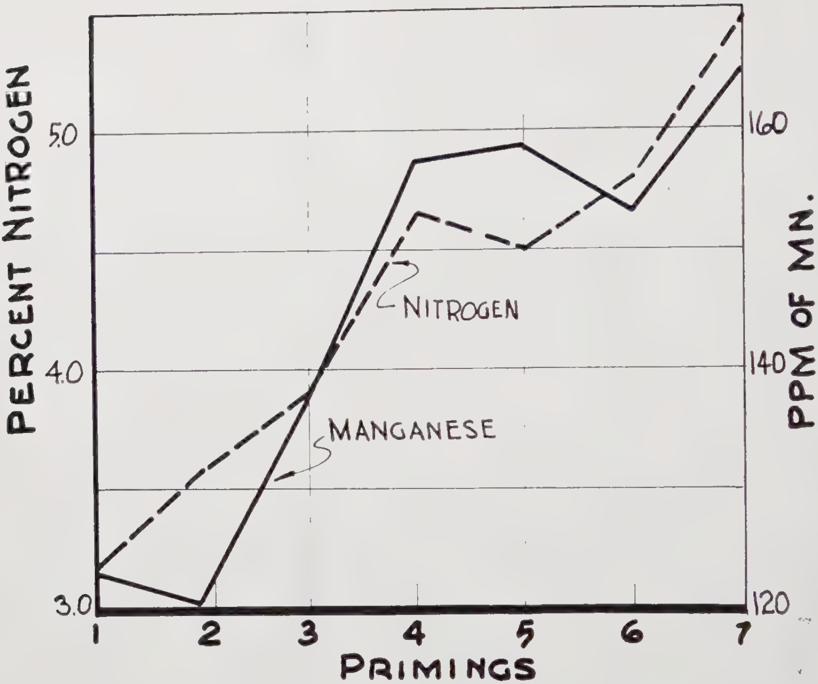

Figure 6. The total nitrogen and maganese found in cigar-wrapper tobacco by primings.

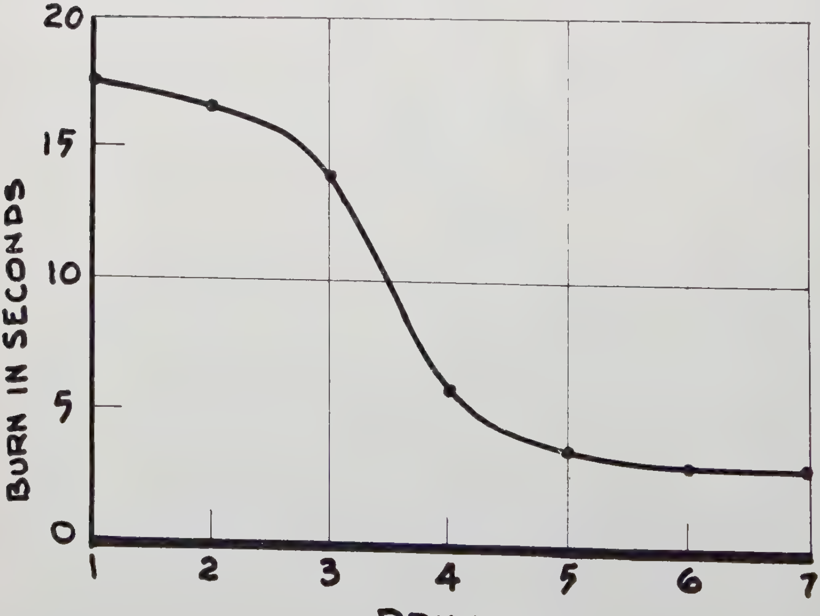

Figure 7. The relation of the position of the leaf (priming) on the average fire-holding capacity of cigar-wrapper tobacco.

of burn decreased rather rapidly after the third priming, it would seem to indicate that when the potassium content of the tobacco leaf falls below about 6.0 per cent, the time of burn is decreased. The increased nitrogen content of the leaves may also adversely affect burn. Both phosphorus and magnesium have a detrimental effect on burn, but since they remain relatively constant throughout the growing period, any effect they might have should be relatively constant.

The ash color remained constant for the first two primings, became considerably darker for the third, and then progressively lighter through the seventh (Figure 8). The light color appears to be directly related to the decreasing potassium content of the leaves.

The analysis of variance was determined on the relationship of priming to the various factors discussed and in each case was found to be highly significant (Tables 2 and 3).

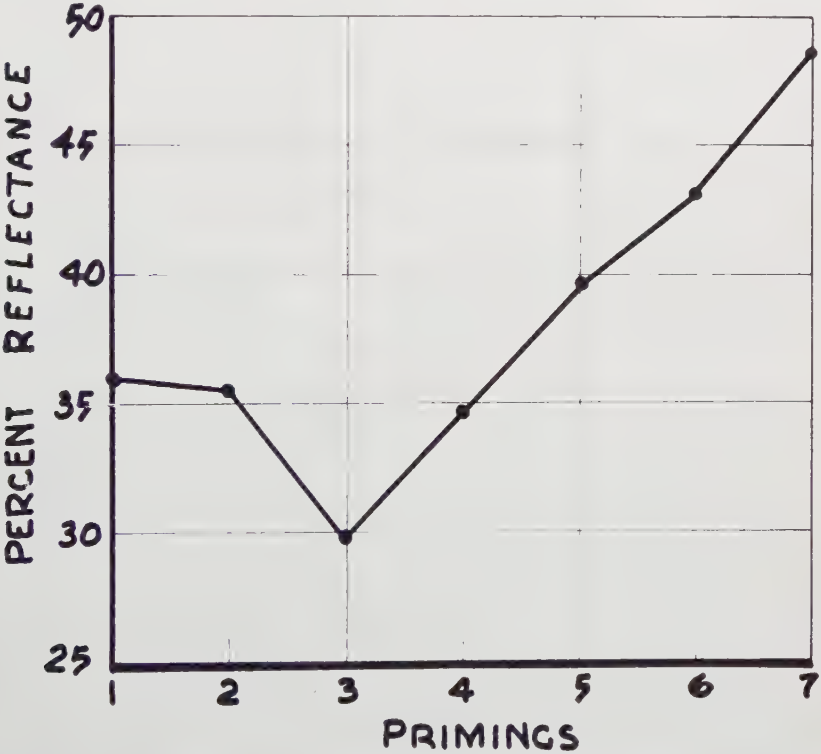

Figure 8. The average per cent reflectance of cigar-wrapper tobacco ash by primings.

SUMMARY

The yield and grade index of the cigar-wrapper tobacco reached a maximum for the fourth and fifth primings and then began to decline, indicating that the best-quality tobacco was being produced during the period of highest yields.

The calcium content of the leaf was found to be at a minimum for the third priming, corresponding rather closely with the soil calcium.

The potassium content decreased with the higher leaf position on the plant, indicating that not enough potassium was applied, or that this is an inherent characteristic of the tobacco plant.

The magnesium and phosphorus values remained more or less constant throughout the priming season.

The nitrogen and maganese content of the leaves increased steadily with higher leaf position on the plant.

The burn test decreased after the third priming which corresponded very closely with the decreased potassium contents of the tobacco leaf.

The ash color became lighter from the third priming through the seventh. This may also be related to the decreasing potassium contents of the leaves.

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The Effect of Rates of Irrigation, Fertilizers and Plant Spacing on the Yield and Quality of Flue-Cured Tobacco in Florida

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Experimental tests conducted at Gainesville in 1949-51 and reported in Agr. Exp. Sta. Bul. No. 572 demonstrated the important effect of irrigation on the production of flue-cured tobacco. The use of irrigation as a tool for tobacco production has increased rapidly in Florida since 1952. Concurrent with this increased use, there developed a need for more information on time and amount of irrigation water to apply. There are several environmental factors that have great influence on the needed information. Among the more important are: distribution of rainfall, moisture-holding capacity of the soil, climatic factors and stage of growth of plants.

Plant growth is determined to a large extent by the way in which the environment for the plants is controlled, therefore in addition to the above mentioned factors, fertilization, number of plants per acre, as well as disease complexes of the soil, are also important. Maximum growth is important, however, optimum returns from tobacco must be measured by certain other criteria, the most important of which is quality of leaf.

Tests were conducted in 1953-55 with different rates of irrigation, fertilizer levels and plant populations to provide additional information on tobacco irrigation.

EXPERIMENTAL PROCEDURE

The soil type was Norfolk fine sand having a pH of 5.5 to 5.7. The experimental area was planted to rye during the fall of 1951 and left fallow after harvesting the rye until the beginning of this experiment.

Three irrigation levels were used in this experiment. Throughout, these levels will be referred to as "high", "medium" and "low".

In a preliminary experiment, conducted during the 1952 tobacco season, soil samples were taken daily from a tobacco field adjoining the experimental area and moisture determinations were made in order to estimate the daily water use by tobacco at Gainesville on Norfolk fine sand. This study showed the average daily use for 13 consecutive seven-day periods, beginning with transplanting and extending through the second "priming", to be .06, .08, .10, .11, .13, .16, .22, .25, .22, .16, .15, .14 and .13 inches. These water use figures form the basis for the irrigation treatments used during each of the three years in the 1953-55 experiment.

The "medium" rate was assigned daily use values identical to those obtained in the 1952 study. Correspondingly, the "low" rate was one-third less and the "high" rate was one-third greater than the "medium" rate.

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Table 1 shows the actual daily use rates assigned the three irrigation treatments.

It was determined by conventional methods that the average available moisture at field capacity in the field used for this experiment was .390 inch for the top six inch depth of soil, .433 inch for the seven to 12 inch depth and .433 for the 13 to 18 inch depth. In order that the plants treated with the "medium" rate of water would not suffer from a lack of soil moisture between irrigation applications (provided the "medium" rate was approximately accurate), a sufficient amount of irrigation water was applied to return the soil moisture to field capacity after not more than an estimated 70 percent of the available soil moisture had been used. The soil was irrigated to a depth of 6 inches during the first three weeks after transplanting, 12 inches for the next two weeks and 18 inches for the remainder of the season.

A simple bookkeeping procedure was used to determine the time and amount of irrigation water to apply. All plots were irrigated at the time of transplanting with a sufficient amount of water to bring the soil to field capacity. Soil moisture deficiencies were accumulated daily at the rates shown in Table 1. When the deficiencies equalled the amounts outlined in the preceding paragraph, irrigation water was applied. Precipitation was deducted from the accumulated deficiencies. When precipitation exceeded the accumulated deficiency, the amount in excess was considered as lost to the tobacco plants.

TABLE 1.—AVERAGE DAILY USE RATES ASSIGNED TO THE "HIGH", "MEDIUM" AND "LOW" IRRIGATION TREATMENTS.

Period After Transplanting (Days)	"Low" (Inches)	"Medium" (Inches)	"High" (Inches)
1 - 7	.040	.060	.080
8 - 14	.053	.080	.107
15 - 21	.067	.100	.133
22 - 28	.073	.110	.147
29 - 35	.087	.130	.173
36 - 42	.107	.160	.213
43 - 49	.147	.220	.293
50 - 56	.167	.250	.333
57 - 63	.147	.220	.293
64 - 70	.107	.160	.213
71 - 77	.100	.150	.200
78 - 84	.093	.140	.187
85 - 91	.087	.130	.173

For the 1953 tests, fertilizer of 4-8-12 analysis was applied in two applications: 600 pounds before transplanting and 600 pounds to the side approximately three weeks after transplanting. The fertilizer mixture also contained 2 units of magnesium oxide and 2 units of chlorine. Plant populations of 7,500 and 10,00 plants per acre were chosen.

Four plant populations were tested in 1954—5,000, 7,500, 10,000 and 12,500 plants per acre. The same fertilizer analysis was used as in 1953. All of the phosphoric acid, magnesium oxide and chlorine was applied before transplanting. The nitrogen and potash was applied in four different treatments. These treatments are shown in Table 2.

In 1955, the same plant populations were used as in 1954; however, instead of several split applications of fertilizer, four different rates were used—1,200, 1,500, 1,800, and 2,100 pounds per acre of a 4-8-10 fertilizer containing two units of chlorine and two units magnesium oxide. Fertilizer was applied to all the plots in split applications: one-half before transplanting and one-half three weeks later.

The soil for all tests for all years was treated with ethylene dibromide-85 at the rate of two gallons per acre.

The tobacco from all plots was measured for yield and quality. After the tobacco was cured and sorted, it was graded by the U.S.D.A. Tobacco Grading Service. The season's average price by grades was used to compute dollar values. High quality is defined as the top four grades from the group classifications: primings, lugs, cutters, smoking leaf and leaf.

EXPERIMENTAL RESULTS

1953

Estimated daily use requirements, shown in Table 1, required 11.6, 8.0 and 4.3 inches of irrigation water for the "high", "medium" and "low" treatments.

Irrigation and rainfall data for 1953 are shown in Table 3 and it should be noted that total water, rainfall and irrigation in inches ranged from 30.1 for the "high" rate to 22.8 for the "low" rate.

The wettest year on record in Florida was 1953 when more than 18.5 inches of rainfall were recorded during the 90-day tobacco season. The distribution was poor and for that reason the "low" irrigation treatment was irrigated seven times for a total of 4.3 inches. Thus, the 4.3 inches of irrigation added to the 18.5 inches of rainfall gave 22.8 inches of total water. This is nearly eight inches more than is considered necessary for high yields of good quality tobacco. See Table 4 for production and quality of production in 1953 as affected by irrigation treatments.

Ten thousand plants per acre produced 134 pounds more tobacco than 7,500 plants, but was worth only $36 more per acre. There was a 10.3 per cent increase in high-quality tobacco from 7,500 plants per acre as compared to 10,000 plants per acre. (See Table 5 for a summary of plant population effect). A portion of the overall low yield in 1953 may be attributed to the leaching of part of the fertilizer by the exceedingly heavy rains immediately after transplanting.

1954 Results

Rainfall distribution in 1954 was greatly different than in 1953 with only one-half as much occurring. Only 3.5 inches of rainfall occurred during the first 57 days of growth, or 6.5 inches less than in 1953. Three inches occurred within three weeks after transplanting. This was approximately one inch more than the estimated needs of the crop. From the twenty-first to the fifty-seventh day after transplanting only .50 inches of rainfall occurred, whereas during this 5-week period of growth, according to the daily use requirement (See Table 1), over 6 inches was needed. Therefore, irrigation was of much importance during this 35-day drought. Rainfall plus irrigation coincided closely with the estimated

TABLE 2.—FERTILIZER TREATMENTS—1954.

Name of Treatment	Date and Amount of N and K Application									
	April 1		April 15		May 1		May 15		Total	
	N	K	N	K	N	K	N	K	N	K
F_1	48	144	....	....	....	....	....	....	48	144
F_2	24	72	24	72	....	....	....	....	48	144
F_3	24	72	12	36	12	36	....	....	48	144
F_4	24	72	12	36	6	18	6	18	48	144

TABLE 3.—TOTAL RAINFALL, TOTAL IRRIGATION, AND NUMBER OF IRRIGATION APPLICATIONS—1953-1955.

Year	Irrigation Treatment								
	"High"			"Medium"			"Low"		
	1953	1954	1955	1953	1954	1955	1953	1954	1955
Rainfall, Inches	18.52	9.70	9.00	18.52	9.70	9.00	18.52	9.70	9.00
Number of Irrigations	16	20	19	11	14	15	7	9	8
Total Irrigation Water Applied, Inches	11.63	13.77	12.92	8.00	8.90	10.19	4.30	5.82	4.98
Total Water, Rainfall and Irrigation, Inches	30.15	23.47	21.92	26.52	18.60	19.19	22.82	15.52	13.98

TABLE 4.—THE EFFECT OF IRRIGATION ON TOTAL YIELD, QUALITY AND VALUE OF TOBACCO—1953-1955.

Year	Irrigation Treatment								
	"High"			"Medium"			"Low"		
	1953	1954	1955	1953	1954	1955	1953	1954	1955
Yield, Lbs./Acre	1,726	1,864	2,169	1,720	1,845	2,362	1,786	1,901	2,088
High Quality, Percent of Total Yield ..	66.2	88.8	72.6	74.0	88.2	73.3	64.5	87.7	70.8
Value, Dollars/Acre ..	929	916	1,068	957	1,001	1,173	926	1,030	982

1955 Yield differences significant at .05 level.
1955 Quality differences significant at .01 level.
1955 Value differences significant at .01 level.
Other differences not significant at .05 level or higher.

TABLE 5.—The Effect of Plant Population on Total Yield, Quality and Value of Irrigated Tobacco—1953-1955.

Year	Population, Plants/Acre											
	5,000			7,500			10,000			12,500		
	1953	1954	1955	1953	1954	1955	1953	1954	1955	1953	1954	1955
Yield, Pounds/Acre		1,601	2,060	1,676	1,828	2,182	1,810	1,830	2,319		1,983	2,266
High Quality, Percent of Total Yield		89.6	72.0	73.2	87.8	73.5	63.5	89.3	74.4		86.6	66.1
Value, Dollars/Acre		878	983	918	998	1,089	956	997	1,168		1,058	1,059

1953 Yield differences significant at .05 level.
1953 Quality differences significant at .05 level.
1954 Yield differences significant at .05 level.
1955 Value differences significant at .01 level.
Other differences not significant at .05 level or higher.

water requirement and expected rainfall. Tobacco on the "low" irrigated treatment was irrigated only four times during the 35-day drought and this amount was inadequate to maintain a healthy growing plant. The drought was broken by two rainfalls which totaled 6.2 inches within a week. As a result of this rain, the "low" irrigated tobacco grew very fast for a few days; however, another drought of more than three weeks followed and tobacco leaves on the "low" irrigated plants were severely damaged by the hot and dry weather. Two irrigations were required during this drought for the "medium" rate, and three irrigations for the "high" rate. Both of these rates appeared to be adequate. Table 3 shows the total rainfall, total irrigation and the number of irrigation applications in 1954.

The yield of tobacco varied from 1,684 pounds for the "high" irrigation rate to 1,801 pounds for the "low". The percent of high quality tobacco produced was approximately the same for all irrigation treatments in 1954, however, the yields from the "high" rate of irrigation were 217 pounds lower than those from the "low" irrigation rate, and this tobacco was worth 124 dollars. Thus, the estimated water needs of tobacco was more nearly equaled by the "low" irrigation treatment than by the "medium" or "high" treatment. Table 4 shows the effect of irrigation on the total yield, quality and value of tobacco in 1954.

Split application of fertilizer (F_2—50 percent before transplanting and 50 percent 15 days later—see Table 2) produced the highest yield, quality and dollar value. See Table 6 for results of split fertilizer applications.

The effect of plant populations is given in Table 5. There was a yield increase of 227 pounds when the number of plants per acre was increased from 5,000 to 7,500. The increase in plants from 7,500 to 10,000 per acre only increased the yield by two pounds, whereas the increase from 7,500 to 12,500 produced an increased yield of 167 pounds per acre. The increased value per acre from the 227 pounds of tobacco was 120 dollars, and for the 167 pounds it was 60 dollars. This is a value of 52.5 and 35.8 cents per pound, respectively. The indication is a poorer leaf quality from the 12,500 plant population than the 7,500 plant population. The additional 5,000 plants was probably not economical when

TABLE 6.—The Effect of Split Fertilizer Applications on Total Yield, Quality and Value of Irrigated Tobacco—1954.

	Number of Fertilizer Applications and Percent of Total/Application			
	F_1 100%	F_2 50%-50%	F_3 50%-25%-25%	F_4 50%-25%-12.5%-12.5%
Yield, Pounds/Acre	1,773	1,898	1,817	1,753
High Quality, Percent of Total Yield	84.6	90.2	88.9	89.2
Value, Dollars/Acre	941	1,052	978	959

Differences for yield, quality and value significant at .01 level.

it is considered that the added cost for plants, labor, insecticide, curing and marketing had to be charged to the 60 dollars more per acre returned by the 12,500 plant population.

1955 Results

There was actually less rainfall in 1955 than in the other years of this study and the distribution was again poor. During the first week after transplanting there was approximately 1.75 inches of rainfall. This was almost equal to a full three weeks supply of moisture based on estimated daily use (Table 1). After the first week there was only .50 inches of rainfall for the next 44 days, thus, only 2.25 inches of poorly distributed rainfall occurred during the first seven weeks of growth. In comparing the predicted water requirement with the rainfall, there was a deficiency of 3.8 inches for the first seven weeks of growth. During this 44-day drought the "low" rate of irrigated tobacco received water by irrigation six times and the "medium" rate 10 times. Between the 50th and 59th day of growth a total of two inches of rainfall occurred in four separate rainfalls. This amount was not enough for the ten day period because tobacco uses approximately .25 acre inch per day during the seventh through the ninth week of growth.

Tobacco produced with the "low" irrigation treatment grew vigorously during the period between the 50th and 59th day after transplanting; however, there was little reserve moisture available to the plants to carry them through the next 19-day drought which occurred between the 60th and 78th day of growth. The 19-day drought was very damaging to the "low" irrigated tobacco and the two irrigation applications made, served only to prevent a complete collapse of the tobacco. This was not adequate to provide satisfactory growth and the yield and quality were reduced. Between the 78th and 90th day after transplanting there was 4.75 inches of rainfall. This rainfall occurred too late in the season to be of much value to the "low" irrigated crop. See Table 3 for rainfall and irrigation amounts and distributions.

In 1955 the "high" rate of irrigation produced 2,169 pounds of tobacco, the "medium" rate, 2,362, and the "low" rate 2,088 pounds per acre. There was a spread of 105 dollars between the "high" and "medium" rate and 191 dollars per acre between the "medium" and "low" rate of irrigation. These yields are somewhat better than the yields for the two previous years, and this may be due to a better distribution of rainfall plus irrigation.

It is reasonable to conclude that water distribution and the amount applied was approximately correct for the "medium" treatment and the "high" rate was probably in excess of plant requirements and caused some leaching of the fertilizer. See Table 4 for a summary of the effect of irrigation on the yield, quality and value of tobacco in 1955.

Table 7 gives a summary of the effect of fertilizer amounts on the yield, quality and value of tobacco in 1955. Results of the fertilizer rates tests show that 2,100 pounds of fertilizer per acre produced only 129 pounds more tobacco than 1,200 pounds. This 129 pounds of tobacco has a gross value of only 29 dollars which little more than paid for the added fertilizer. The 1,500-pound per acre rate of fertilizer

produced within six dollars of the value of the 2,100-pound per acre rate of fertilizer. Therefore, the higher rates of fertilizer did not prove economical in 1955.

The effect of plant population on yield and quality of tobacco is shown in Table 5. Ten thousand plants per acre produced the highest yield of tobacco in 1955. It was 259 pounds more than the 5,000 plants per acre population, 137 pounds more than the 7,500 and 53 pounds more than the 12,500. The percentage of high quality tobacco was 8.3 percent higher from the 10,000 plants than from the 12,500 plants per acre. The value per acre was increased 79 dollars for 7,500 plant, 185 for 10,000 plants and 109 for 12,500 plants over the 5,000 plants per acre population in 1955.

TABLE 7.—THE EFFECT OF FERTILIZER AMOUNTS ON TOTAL YIELD, QUALITY AND VALUE OF IRRIGATED TOBACCO—1955.

	Fertilizer, 4-8-10, Pounds/Acre			
	1,200	1,500	1,800	2,100
Yield, Pounds/Acre	2,135	2,180	2,250	2,264
High Quality Percent of Total Yield	74.8	73.4	70.5	67.8
Value, Dollars/Acre	1,056	1,079	1,079	1,085

Yield differences significant at .01 level.
Quality differences significant at .01 level.
Value differences not significant.

SUMMARY

It appears from the data reported herein that there is a definite correlation between the rate and distribution of rainfall and irrigation, fertilization practices and plant population.

The number of times irrigation was required varied for the different years. This was a result of variations of the amount and distribution of rainfall for the three years. The years encompassed by the experiments represent what could be commonly called wet (1953), average (1954) and dry (1955) years.

In the discussion of the three years data, little emphasis was given the "high" and "low" irrigation treatment. The reason for this was that the "medium" rate had been selected as an estimation of the optimum water rate that was needed to grow a good crop of tobacco. The problem was to distribute the amount of irrigation with rainfall. The "high" rate and "low" rate were tested to determine the accuracy of the estimation of the "medium" rate. The "high" rate of irrigation was not particularly harmful to the tobacco as shown by the data; however, greater labor and power costs were required. The "low" rate was not sufficient to furnish the maximum yield of high quality tobacco for all three years. Thus, the results of this study indicate that the "medium" rate was a good estimate of the water needed for tobacco in Florida.

Another result to be considered is the effect of plant populations on total returns of the crop. A 12,500 plant population is high for tobacco and invariably with irrigation, the first two primings contain a high percentage of nondescript tobacco. This is primarily a result of the shading of lower leaves. Also, added cost for plants, transplanting, harvesting and fuel make the economic returns from thickly populated tobacco questionable. Five thousand plants per acre produced excellent quality tobacco, but the yield was depressed considerably. Plant populations of 7,500 and 10,000 per acre gave best results during the three years.

Results of these tests indicate that the fertilizer requirement for irrigated tobacco is approximately the same as for non-irrigated tobacco. Of the fertilizer rates tested, 1,500 pounds per acre proved to be the most feasible. Best results were also obtained by applying fertilizer in two applications; one-half prior to transplanting and the remaining one-half approximately three weeks after transplanting.

Recent market and processing trends have shifted from the lighter, milder type of leaf. Therefore, to continue to supply the acceptable kind of leaf tobacco with high economic returns, the grower will be required to blend good varieties, fertilization, cultural practices, irrigation and harvesting and curing procedures.

A Study of Some Laboratory Methods for Determining Calcium and Magnesium

H. L. Carver and W. K. Robertson*

The levels of calcium and magnesium in the soil, as indicated by many of the chemical methods, are not always correlated with crop response. In some soils, the exchangeable calcium level as determined by extraction with ammonium acetate and subsequent flame analyses approaches zero and yet crops do not give yield responses to lime. Similarly, the exchangeable magnesium level may be low and yet crop yield responses are not always obtained for magnesium applications(3). The purpose of this paper is to compare the standard methods with other methods reported in the literature, to see if one can be found that correlates more favorably with crop response.

Gilbert, Hawes and Beckman(8) were the first to determine calcium on the Beckman flame spectrophotometer. They used standards containing only the element determined and the common matrix anion. Brown *et al.*(4) indicated that the 285.2 mu line could be used with very little interference from elements normally found in plant ash solutions. Horn(9) summarized the problems involved in determining magnesium and concluded that the foreign ions or molecules in the unknown solution are often the most troublesome factors in flame spectrophotometry. In his research, he was able to remove most of the interferences by passing the unknown solution through an anion exchange resin. Similarly, other workers(2,13) have improved the methods for determining calcium on the flame spectrophotometer by removing interferences. The Florida State Chemist[1] determines calcium and magnesium in fertilizers on the flame spectrophotometer by the use of an additional buffer. Others(4,12,15) have introduced buffers, or additional substances, into the unknown solutions to determine the metals found in plant, soil and other materials.

Many workers(5,6,10,11) have used chemical methods to determine calcium and magnesium in plant material and soil. The oxalate method for calcium(1,5) is the accepted standard but is tedious and time-consuming.

The most popular chemical method for magnesium(6) depends on the color lake reaction with $Mg(OH)_2$ and either titan or thiazole yellow which is stabilized with starch. Because of the fading of the color lake, the determinations are not easily reproduced and are sometimes affected by the presence of aluminum, calcium, copper, iron, manganese, phosphorus, perchloric acid and ammonia. The latter may be compensated for but usually the solution is subject to a limited range of magnesium concentration, or readily fades or precipitates, in an alkaline medium. To improve the thiazole yellow method, Mehlich(10) used sodium polyacrylate and triethanolamine to stabilize the color lake.

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METHODS

The precipitation of calcium as the oxalate followed by permanganate titration(1) was used as the reference method for calcium. Corn plant samples obtained from flatwood, Klej fine sand, Norfolk loamy fine sand and Red Bay fine sandy loam and soil samples from the Klej fine sand were analyzed as above and the results were compared with the Beckman B spectrophotometer with an oxygen-acetylene attachment at the 622 millimicron wavelength. The soils tested had a wide range of phosphorus, iron and aluminum(7). To see if these and other ions interfered with the flame analyses, two methods were used. The first employed a buffer solution containing 5.58 grams of dibasic ammonium phosphate and 1.38 grams of ammonium sulfate per liter of solution made .1 N with HCl. The buffer solution was added to the test solution in a 1:1 ratio. The second was carried out by passing the test solution through an anion exchange resin.

A series of standard solutions from 0 - 200 ppm were made using calcium carbonate dissolved in .1 N HCl. A set of these standards was passed through the anion exchange resin along with the unknown. The phosphate-sulfate buffer was also incorporated with a set of standards.

Preliminary tests indicated that sodium polyacrylate(10) was superior to starch(6) as a stabilizer in the formation of the color lake reactions in the magnesium determinations. Because it correlated with the A.O.A.C. method(1), it was used in this publication and is referred to as the "improved colorimetric method."

Color transmission for magnesium was read on a Cenco-Sheard-Sanford photolometer using a 525 millimicron green filter.

The plant materials analyzed for calcium were used for the magnesium tests; oat plant material from the Klej fine sand was also included.

Magnesium was determined by the improved colorimetric method before and after removing interferences with the resin(9). It was also determined by the colorimetric starch method. Results from the chemical methods were compared with those from the Beckman D U spectrophotometer with photomultiplier before and after passing the test solution through the resin and also with results from the D U using the ultraviolet and hydrogen discharge lamps. Magnesium was also determined in the D U with the hydrogen flame using a buffer(12) made as already described for calcium determination, to remove intereferences from phosphate and sulfate. The flame emission spectrum was obtained in the ultraviolet range at 285.2 millimicron wave length.

A series of magnesium standards from 0 to 100 ppm were made up in .1 N HCl using magnesium oxide. These standards were passed through the resin and treated with buffers similarly to the calcium standards. These were used in the flame methods. An additional set of standards was made as above for the chemical methods except magnesium sulfate ($MgSO_4 7H_2O$) was used and the concentrations were from 0 to 12.2 ppm.

In the preparation of the soil and plant samples, one gram of plant material or five grams of soil were ashed in a muffle furnace at 450C° for one hour. The ash was dehydrated and reduced on a steam bath to a common matrix with 40 per cent hydrochloric acid, washed into 100 milliliter volumetric flasks with 0.1 N HCl and filtered through No. 32 Whatman filter paper.

Flame spectrophotometer analyses were made from plant and soil extract without further dilution, except when the buffer solution was added.

For the chemical determination of calcium, no further dilution was made but in the case of magnesium by the chemical method, it was diluted five or ten times.

RESULTS AND DISCUSSION

The effect of the buffer solution on the standard calcium curve as determined on Beckman B spectrophotometer is shown in Figure 1. The curves indicate that sensitivity was reduced by the buffer at lower calcium concentrations.

TABLE 1.—Sensitivity of the Calcium Methods as Affected by Calcium Level in Corn Ear Leaves.

Chemical Using Oxalate		Flame Using Beckman B					
			Dev.*	Using Resin	Dev.*	With Buffer	Dev.*
			Flatwood Soils				
1	.29	.08	—.11	.33	+.04		
2.	.33	.08	—.25	.37	+.04		
3	.38	.10	—.28	.44	+.06		
4	.47	.13	—.34	.55	+.08		
5	.13	.07	—.06			.22	.09
6	.22	.10	—.02			.26	.04
7	.26	.11	—.15			.35	.09
8	.33	.15	—.18			.57	.14
			Klej Fine Sand				
1	.29	.07	—.12	.32	.03		
2	.38	.18	—.20	.39	.01		
3	.47	.13	—.34	.53	.05		
4.	.52	.18	—.34	.52	.00		
			Norfolk Loamy Fine Sand				
1	.54	.39	—.15			.87	+.33
2	.70	.41	—.29			1.00	+.30
3	.80	.64	—.16			1.05	+.25
4	.90	.55	—.35			1.08	+.18
			Red Bay Fine Sandy Loam				
1.	.18	.17	—.01			.33	+.15
2	.36	.23	—.13			.44	+.08
3	.42	.19	—.23			.54	+.05
4	.58	.24	—.34			.63	+.05
Average	.43	.21		.43		.61	
Ratio**		.49		1.00		1.42	

* Deviation from chemical method using oxalate.
** Ratio of various methods to the chemical method.

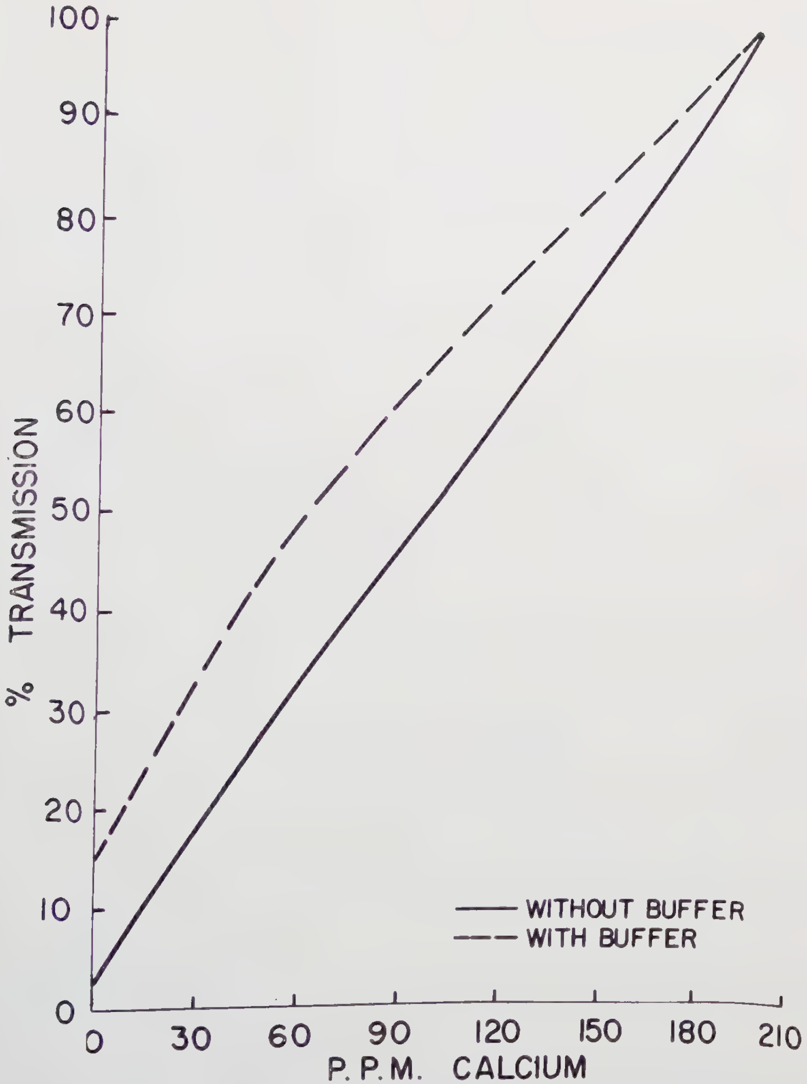

Figure 1. Effect of the phosphate and sulfate buffer on the calcium determination using the flame.

Samples containing a wide range of calcium levels are compared on four soils with the flame method before and after removing or compensating for interferences with the resin and buffer respectively, in Table 1. The flame method was lower in all cases when intereferences were not removed or compensated for. After removing interferences with the resin, the flame gave values that correlated very closely with the chemical method on the flatwood and Klej fine sand. When phosphate and sulfate were added as a buffer, the values correlated as well as when

the resin was used on the flatwood soil and the Red Bay fine sandy loam, but were considerably higher on the Norfolk loamy fine sand. The latter soil is high in aluminum which was not compensated for.

The data from the Klej fine sand in Table 2 indicate that all methods using the flame gave values that were considerably lower than those obtained using the chemical method. The ratios shown at the bottom of the table amounted to 0.05, 0.02, 0.04 and 0.12 for uncompensated precipitation with ammonium hydroxide, precipitation plus resin and compensation with buffer, respectively. It is evident from these data that the flame methods selected for soil samples were of limited value. In most cases, however, they were relative, with the best relation where the buffer was used.

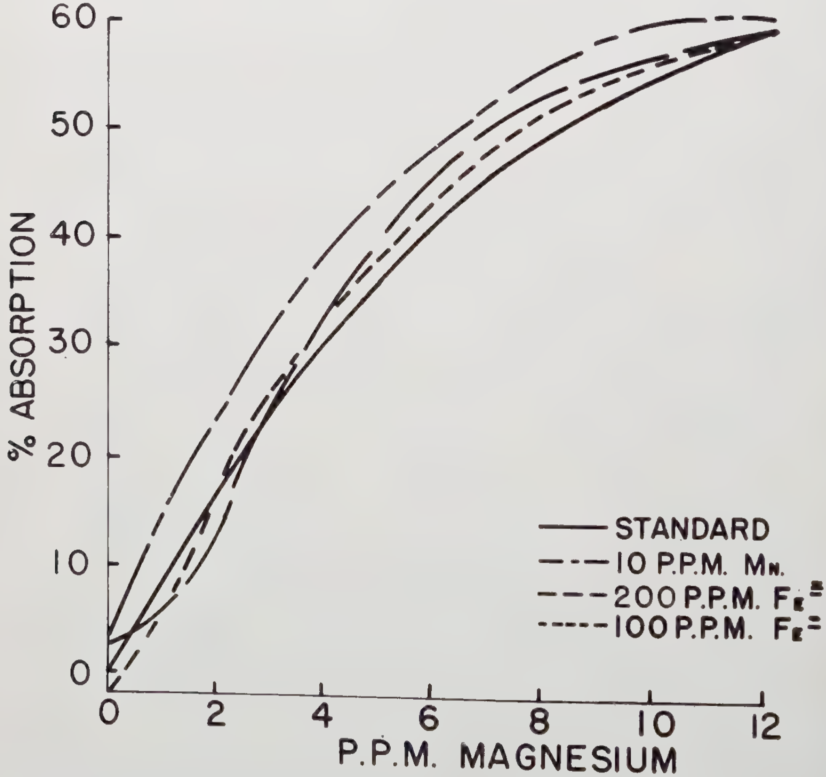

Figure 2. Effect of the ferrous, ferric and manganese ions on the colorimetric determination of magnesium.

Magnesium was determined on standards using the thiazole yellow and sodium polyacrylate (improved colorimetric method) from 0 to 12.2 ppm.

The effect of 0 to 30 ppm copper, 0 to 30 ppm phosphorus, 0 to 30 ppm manganese, 0 to 300 ppm ferric and ferrous iron, .1 N to .2 N HCl

TABLE 2.—CALCIUM FOUND IN KLEJ FINE SAND IN LBS./ACRE USING DIFFERENT METHODS.

Treatment Lbs./A.		Chemical Method*	Flame Using Beckman B		Interferences Removed with NH_4OH					
$CaCO_3$	MgO			Dev.**	Ppt†	Dev.**	+ Resin	Dev.**	With Buffer	Dev.**
0	0	560	70	—490	25	—535	50	—510	145	415
0	25	360	70	—290	25	—335	50	—310	155	205
750	0	920	80	—840	25	—895	50	850	185	735
750	25	1560	80	—1480	40	—1520	75	—1485	180	1380
1500	0	3320	85	—3320	50	—3270	80	— 3240	190	3130
1500	25	2480	80	—2400	50	—2430	50	—2420	210	—2270
Average		1530	78		36		61		178	
Ratio‡			0.05		0.02		0.04		0.12	

* Determined using oxalate permangante titration.
** Deviation from chemical method.
† Accomplished by using 1.ON NH_4OH.
‡ Ratio of various methods to the chemical method.

and 0 to .9 N NH_4OH on the standard curve was determined (Figures 2, 3). These curves show that manganese, ferric iron, ferrous iron, copper and phosphorus interfered with this method at the following concentrations: 10 ppm, 200 ppm, 100 ppm, 20 ppm and 15 ppm, respectively. Since these levels are above those normally found in the test solutions(14), it was felt that these ions normally would not cause errors.

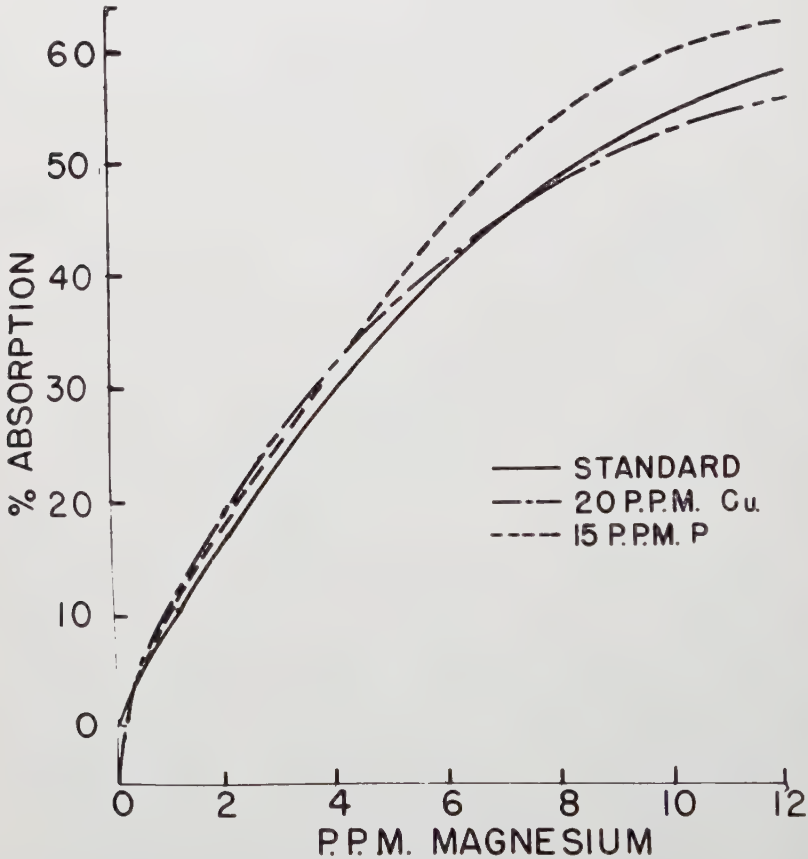

Figure 3. Effect of copper and phosphorus on the colorimetric determination of magnesium.

Ammonia and HCl caused discrepancies at concentrations of 0.5 N and .03 N, respectively. These data are shown in Figure 4.

Further tests showed that 0.5 N ammonium hydroxide and 0.25 N perchloric acid caused fading of the color lake when the standard contained 10 ppm phosphorus. These data are not reported.

The effect of the buffer on the magnesium determination, shown in Figure 5, indicates that sensitivity was lost at low concentrations.

The improved chemical method for magnesium(10) was compared on corn ear leaf samples containing .40 to .48 per cent calcium with other

TABLE 3.—Percent Hydrochloric Acid Soluble Magnesium Found in the Ash from Corn Ear Leaves Using Different Methods of Analysis.

Treatment Lbs./A.		% Ca Using Oxalate	% Mg by Chemical Methods					Beckman DU and Quartz Spectrophotometer							
			Improved Chemical			Using Starch	Devi- ation*	Ultra Violet Lamp	Devi- ation*	Hydrogen Discharge Lamp	Devi- ation*	Hydrogen Flame			
MgO	$CaCO_3$			With Resin	Devi- ation*								Devi- ation*	With Resin	Devi- ation*
0	0	.40	.202	.292	.090	.094	.108	.365	.163	.088	– .114	.375	.173	.406	.204
0	2000	.44	.108	.107	—.001	.097	.011	.384	.275	.054	– .054	.119	.011	.144	.038
75	0	.40	.424	.413	– .011	.135	.289	.496	.072	.198	– .226	.563	.139	.363	.038
75	2000	.48	.390	.494	.104	.144	.146	.366	– .030	.137	—.253	.663	.273	.538	.148
Average			.281	.326		.118		.403		.119		.430		.363	
Ratio**				1.16		0.42		1.43		0.42		1.53		1.29	

* Deviation from improved chemical method where no interferences removed.
** Ratios of various mehtods to the improved chemical method.

chemical and flame methods (Table 3). The application of 75 pounds per acre of magnesium from magnesium sulfate to Klej fine sand more than doubled the magnesium concentration in the plant as determined by the improved chemical method. Removing interferences with the anion exchange resin increased the magnesium levels, on the average, but results were not consistent with the calcium level. These data and other data reported in Tables 4 and 5 indicate that there may have been a chemical reaction between the magnesium and the anions in the resin which took place to a greater or lesser degree, depending on the efficiency of regeneration. Using starch gave values consistently lower than those obtained by the improved chemical method.

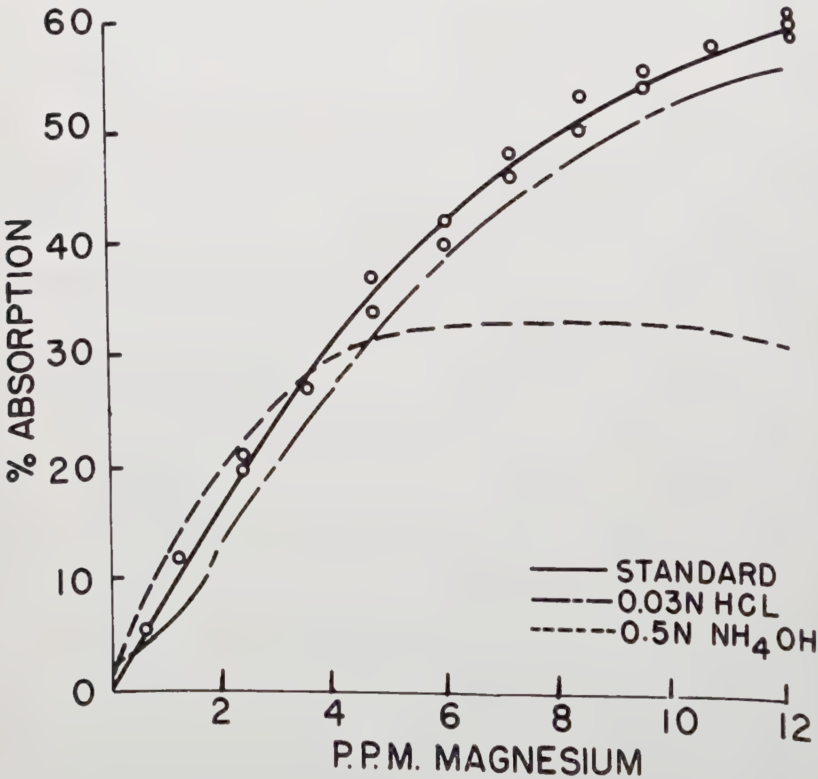

Figure 4. Effect of hydrochloric acid and ammonium hydroxide on the colorimetric determination of magnesium.

Results using the Beckman D U were inconsistent. The ultraviolet lamp gave high values on plant material on soil receiving no magnesium. The hydrogen discharge lamp gave low but relative values. The hydrogen flame gave high but relative values and with resin the values were inconsistent.

Ratios showing the relative amounts of magnesium as determined by the various methods are shown at the bottom of Table 3.

TABLE 4.—SENSITIVITY OF THE MAGNESIUM METHODS AS AFFECTED BY MAGNESIUM LEVEL IN CORN EAR LEAVES AND OATS.

Improved Cehmical Method*				Hydrogen Flame Using Beckman D.U.					
		With Resin	Dev.**		Dev.**	With Resin	Dev.**	With Buffer	Dev.**
USING CORN EAR LEAF									
Flatwood Soils									
1	.082			.044	—.038			.065	—.017
2	.124			.063	—.061			.103	—.021
3	.138			.076	—.062			.133	—.005
4	.150			.064	—.086			.140	—.010
Norfolk Loamy Fine Sand									
1.	.271			.208	—.063			.373	.102
2	.282			.242	—.040			.383	.101
3	.290			.303	.013			.402	.112
4	.300			.327	.027			.403	.103
Red Bay Fine Sandy Loam									
1	.156			.170	.014			.206	.050
2	.179			.145	—.034			.200	.021
3	.194			.175	—.019			.258	.064
4	.226			.163	—.063			.282	.056
Klej Fine Sand									
1	.134	.197	+.063	.175	.041	.154	.020		
2	.275	.239	—.036	.328	.053	.287	.012		
3	.393	.488	+.095	.329	—.064	.642	.249		
4	.417	.370	—.047	.515	.098	.432	.015		
Ave.	.226	.324		.208		.379		.246	
Ratio	....	1.43		0.92		1.68		1.09	
OATS									
Klej Fine Sand									
1	.268	.247	—.021	.142	—.126	.260	—.008		
2	.269	.260	—.009	.165	—.104	.235	—.034		
3	,356	.338	—.018	.197	—.159	.303	—.053		
4	.360	.352	—.009	.228	—.132	.340	—.020		
Ave.	.313	.299		.183		.284			
Ratio†	......	0.96		0.58		0.91			

* Improved chemical method utilizes thiozole yellow and sodium polyacrylate as a stabilizer.

** Deviation from chemical method.

† Ratio of various methods to the improved chemical method.

Results from corn ear leaves in Table 4 on the flatwood, Norfolk loamy fine sand, Red Bay fine sandy loam and Klej fine sand, as well as oat data from Klej fine sand, show similar ratios to those in Table 3. However, deviations tend to be smaller on oats than on corn.

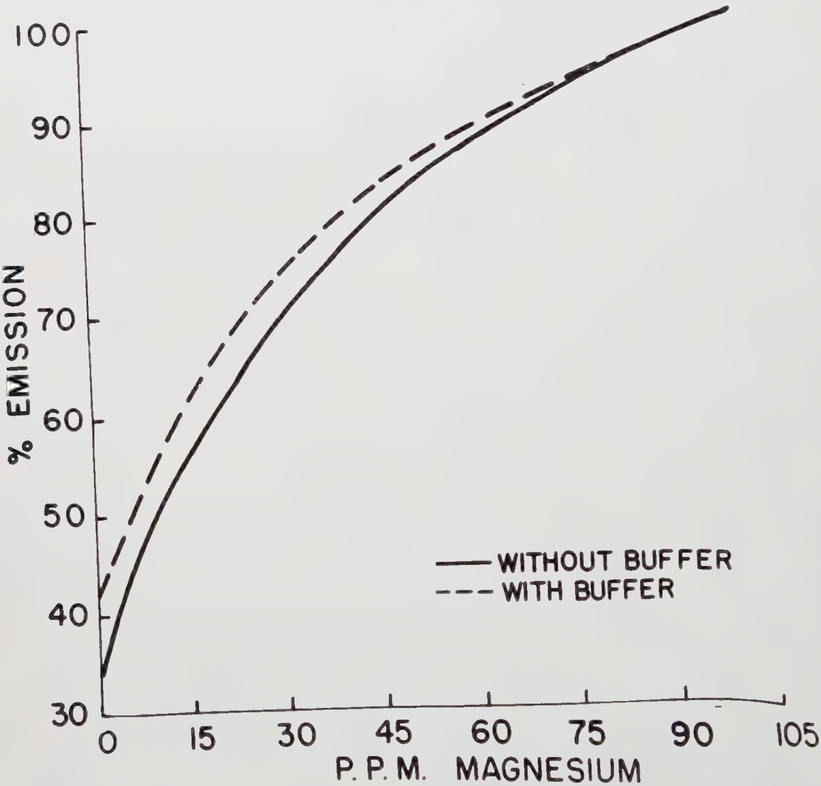

Figure 5. Effect of the phosphate and sulfate buffer on the magnesium determination using the flame.

Chemical analyses of soil samples from the Klej fine sand in Table 5 show that removing interferences with NH_4OH or resin gave low and inconsistent values. All the hydrogen flame methods were lower, on the average, than either of the chemical mehtods and, as compared with the improved colorimetric method, were inconsistent except for the uncompensated flame and the method where the buffer was used. The latter two methods may possibly be used with qualifications.

SUMMARY

A comparison was made between several calcium and magnesium methods using Klej fine sand samples and corn plant material from flatwood soils, Klej fine sand, Norfolk loamy fine sand and Red Bay fine sandy loam.

TABLE 5.—MAGNESIUM FOUND IN KLEJ FINE SAND IN LBS./A. USING DIFFERENT METHODS.

Treatment Lbs./A.		Improved Colorimetric Method					Hydrogen Flame with Beckman D.U.							
			Removing Interferences						Removing Interferences					
MgO	$CaCO_3$		Ppt.*	Dev.**	+ Resin	Dev.**	Uncom-pen-stated	Dev.**	Ppt.*	Dev.**	+ Resin	Dev.**	With Buffer	Dev.**
0	0	267	137	—130	150	—117	70	—197	88	—179	100	—167	80	—187
0	750	322	100	—222	125	—197	85	—237	62	—260	100	—222	109	—213
0	1500	308	112	—196	138	—170	85	—223	50	—258	75	—233	117	—191
25	0	208	92	—116	154	— 54	80	—128	62	—146	100	—108	30	—178
25	750	318	108	—210	144	—174	85	—233	50	—268	100	—218	117	—201
25	1500	308	100	—208	141	—167	80	—228	62	—246	100	—208	127	—181
Average		288	108		142		81		62		96		97	
Ratio			0.38		0.49		0.28		0.22		0.33		0.34	

* Accomplished by using 1 N NH_4OH.
** Deviation from Chemical method where no interfering ions removed.

Using the oxalate permanganate chemical method as a reference for calcium, it was shown for plant material obtained from flatwood soils and Klej fine sand that the Beckman B flame spectrophotometer using the 622 millimicron wave length gave values that were low and inconsistent unless interfering ions were removed with an anion exchange resin. When the latter was done, good correlations were obtained. When a buffer solution containing the phosphate and sulfate ions was added to the test solution to compensate for interfering ions, values were higher than the chemical method by 50 per cent.

On soils the Beckman B flame spectrophotometer gave values amounting to 6 per cent on the average, of those obtained by the chemical methods and usually they were inconsistent.

An improved chemical method for magnesium, in which color was developed with thiazole yellow and stabilized with sodium polyacrylate, was known to compare favorably with the A.O.A.C. method. Results from it were compared using corn and oat plant material and Klej fine sand samples with other chemical methods and methods developed for the Beckman D U spectrophotometer and its attachments.

For both plant and soil samples, it was found that the removal of interferences with the resin gave inconsistent results. On corn ear leaves, the starch method gave low but relative values; the hydrogen discharge lamp gave low results; the ultraviolet lamp gave inconsistent results and the hydrogen flame gave high, but relative, values. Better correlations were obtained on oats than on the corn plant.

On plant material, the improved chemical method was sensitive to the magnesium level of the soil.

ACKNOWLEDGMENTS

The authors wish to thank Drs. Nathan Gammon, Jr., J. G. A. Fiskel, and B. R. Reddy for suggestions and assistance in this study.

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Methods for Analyzing Soil Extracts for Potassium, Calcium and Magnesium Using the Beckman D. U. Flamephotometer

A. S. Baker*

In December of 1955 a soil testing laboratory was established at the North Florida Agricultural Experiment Station. One of the purposes of this installation is to test soil samples as a service to local farmers. In order to enable comparisons of the results of these soil tests with those obtained at the Main Station and elsewhere in the State, it was decided to use the same method of extraction prevalent in most of the rest of Florida(3). This method of extraction involves shaking 5 grams of soil with 25 ml of ammonium acetate solution which is buffered at pH 4.8 for one-half hour. This latter is filtered to obtain a clear filtrate on which the analyses are performed. The author modified the procedure to the extent of introducing a measured volume of air dried and sifted soil (4.1cc) rather than the weighed amount. It is felt that this modification prevents the docking of coarser textured soils and soils of low organic matter content due to their higher volume weights.

Another modification is the addition of 1/8 measuring teaspoon of activated carbon to the soil-extracting solution mixture before shaking. Darco G 60 is used because, according to Peech(2), none of the cations and only a minute quantity of P is removed by this product. This process removes rather effectively all of the colloidal organic matter that would otherwise color the extract. It is not known by the author what effect these organic colloids have on the flame but they would most certainly affect the colorimetric determination of phosphorus.

It was decided to determine quantitatively the amounts of K, Ca and Mg using the Beckman D. U. flamephotometer with a photomultiplier attachment. A hydrogen-oxygen flame served as a source of energy. Since it is well understood that various ions interfere with the flame characteristics of others it was necessary, in the interests of better analytical procedures, to investigate various possible interferences.

Generally, it was felt that most of the soil extracts to be tested would contain less than 100 ppm of Ca, 30 ppm K and 30 ppm Mg. For this reason the investigation of interferences were restricted to concentrations of Ca, K and Mg ranging between zero and the above concentrations. If a few soil extracts do exceed these values it will be a simple matter to dilute them.

PHOSPHATE AND SULFATE INTERFERENCES

Both the sulfate and phosphate ions are found to interfere seriously with Ca and Mg luminosity but not with K. These intereferences are negative as illustrated in Figure 1. Horn(1) proposed that this type of anion interference is due to the formation of Ca and Mg salts in the flame

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Florida Agricultural Experiment Station Journal Series No. 612.

of high melting or boiling points and therefore reduces the amount of ionization and oxide activation of these metals. This reasoning would be in harmony with the fact that the author finds that phosphate and sulfate interferences on Ca and Mg lines and bands appear to be independent of the wavelength used. There is no difference in the amount of interference from phosphate and sulfate ions on Ca, at 422.7, 554 or 622 millimicrons. There is also no difference in interference from these two anions on Mg at 371 or 383 millimicrons. At 285.2 millimicrons for Mg the interference from these two anions is considerably less in terms of percent luminosity. Because of the relatively flat standard curve obtained at this wavelength, there is about the same magnitude of Mg concentration error due to these anion interferences.

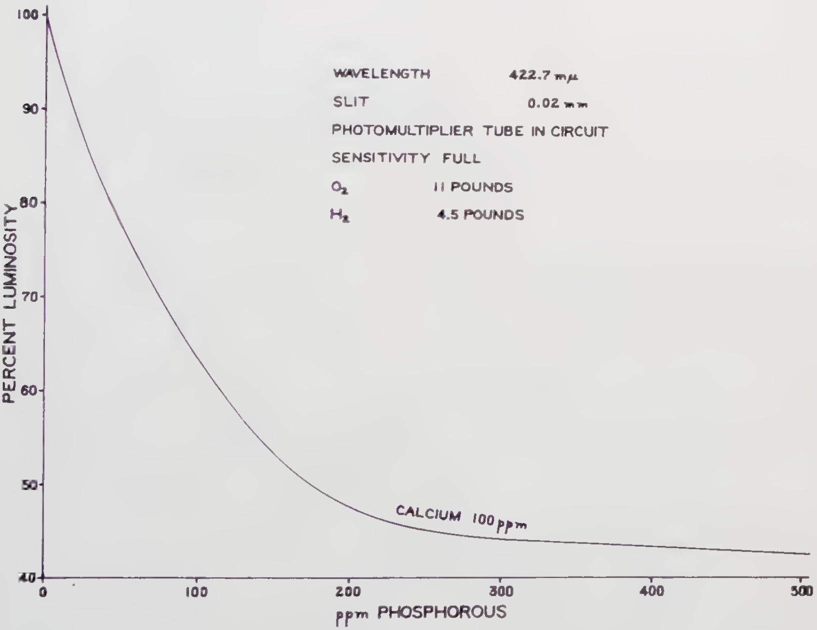

Figure 1. The effect of the phosphate ion on the luminosity of the Ca arc line.

It was decided to attempt the use of what is commonly called a radiation buffer. That is, to bring up the concentration of the interfering ions in the samples and standard solutions to such an extent that there would be no further interference from a small increment of those ions. It may be noted in Figure 1 that phosphorus interference on Ca at 100 ppm reaches a plateau at 300 ppm of P as the phosphate ion. At the same concentration of Ca it was found that a plateau is reached at 150 ppm of S as the sulfate ion. For Mg at 30 ppm these plateau concentrations of phosphate and sulfate ions were much lower. Since interference from phosphate and sulfate ions on Ca and Mg decreases with decreasing concentrations of these cations, it was not necessary to find the plateau values for phosphate or sulfate ions at lower concentrations of Ca and Mg. By bringing up the concentrations of phosphate and sulfate ions to 300

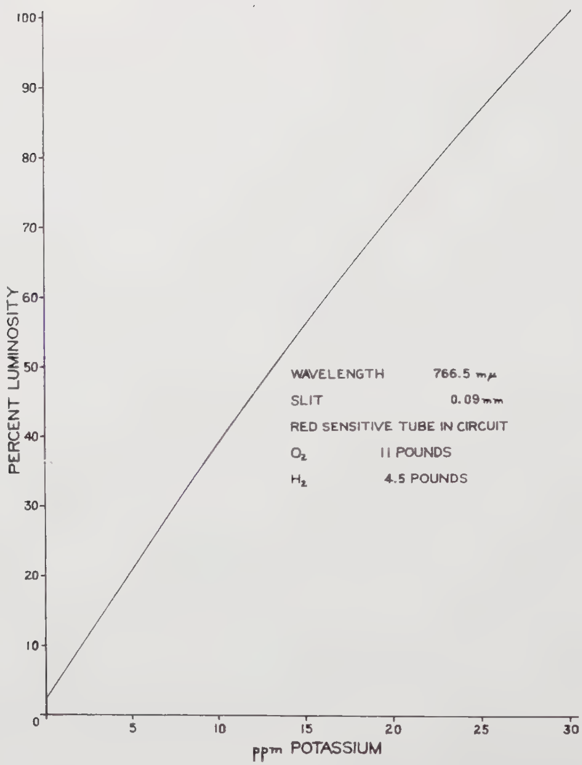

Figure 2. Standard curve for K containing the phosphate-sulfate radiation buffer.

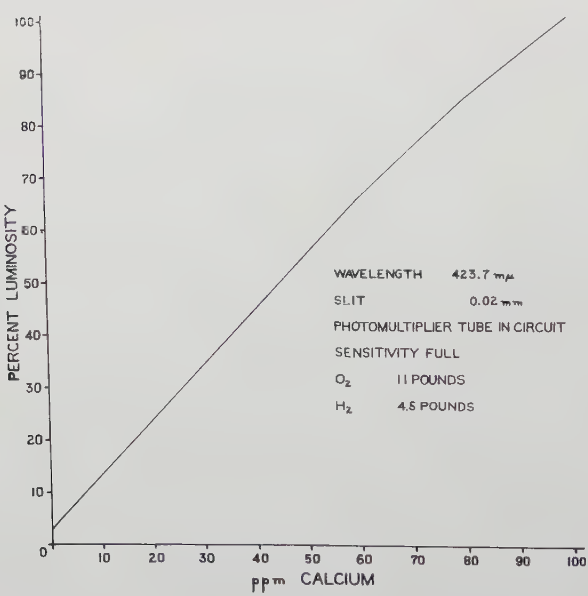

Figure 3. Standard curve for Ca containing the phosphate-sulfate radiation buffer.

ppm P and 150 ppm S in standard and unknown solutions, all possible interference from these two anions should be eliminated.

Workable and reproducable curves were obtained for Ca, Mg and K (Figures 2, 3 and 4) with standards containing 300 ppm P and 150 ppm S. The salts used to make up this radiation buffer were $(NH_4)_2HPO_4$ and $(NH_4)_2SO_4$.

Cation Interferences

Standard Solutions.—All cations investigated were brought into solution in the ammonium acetate extracting solution. The salts used are listed in Table 1.

Cation Interferences on K.—It is apparent from an examination of Table 2 that there is little or no interferences on the K line from the cations tested except from perhaps Na at 100 ppm. This would be equivalent to 1,500 pounds of Na per acre furrow slice. The likelihood of finding a soil with that much Na in the acid leached soils of inland Florida is small. Even if a sample contained that much Na the error would only be about $\frac{1}{3}$ to $\frac{1}{2}$ of a ppm of K when there was actually 30 ppm of K in solution. The other variations noted are small and are probably due to instrumental variations or pipette inaccuracies during dilution.

Cation Interferences on Ca.—Apparently every ion tested interferes with the Ca test but by far the most serious interference stems from Mg (Table 3). The interference from Fe is positive as is that from the lower concentrations of Al. This is probably due to background from several bright arc lines of these elements in close proximity to the 422.7 millimicron line of Ca. This background could probably be eliminated to some extent by switching to the 554 or the 622 millimicron bands of Ca, however, it was found that there would be between 1 and 2 ppm of Al and less than 1 ppm of Fe left in solution after the phosphate-sulfate radiation buffer is added. This does not leave enough Fe to interfere and only enough Al to cause an insignificant amount of interference.

Although it is not important to the purposes of this paper it may be of interest to note that above 6 ppm of Al the interference changes from positive to negative. Probably this is due to the amphoteric properties of Al. This negative interference may stem from the presence of the aluminate anion which can cause interference in the same manner that phosphate and sulfate ions cause negative intereferences on Ca. At the higher concentrations of Al the negative aluminate anion interference begins to dominate over the postive background interferences caused by ionization of the Al cation.

Just what causes the negative interference on the Ca line ($422.7 m\mu$) from Mg, K and Na is not known by the author. However some leads may be obtained as to the causes of these interferences on Ca from the following facts noted by the author:

1. Practically the same amount of interference is noted at 554 and 622 millimicron wavelengths is found at 422.7 millimicrons.

2. In the absence of the phosphate-sulfate radiation buffer the interference from Mg is greatly reduced while Na and K interferences are actually slightly postive (Table 4).

TABLE 1.

Cation	Sources	Cation	Sources
K	KCl	Fe	$FeSO_4.7H_2O$
Ca	$CaCO_3$	Al	$Al_2(SO_4)_3.18H_2O$
Mg	Mg (metal)		
Na	NaCl		

TABLE 2.—Cation Interferences with the K Arc Line at 766.5 mμ.*

Mg ppm	Luminosity Percent	Ca ppm	Luminosity Percent	Na ppm	Luminosity Percent	Fe ppm	Luminosity Percent	Al ppm	Luminosity Percent
0	100.0	0	100.0	0	100.0	0	100.0	0	100.0
6	100.5	20	99.3	6	100.0	2	100.0	2	100.0
10	99.8	40	100.0	10	100.0	4	100.0	4	99.0
20	99.8	60	100.9	20	100.0	6	100.0	6	99.0
40	99.8	80	100.3	40	100.0	8	101.0	8	99.6
		100	100.5	100	101.2	10	101.3	10	100.6
						20	101.0	20	99.0

* All solutions contained 30 ppm K and the radiation buffer.
Phosphorus was not included in the radiation buffer in the Fe and Al solutions because these cations would precipitate with the phosphate ion.

TABLE 3.—Cation Interferences with the Ca Arc Line at 422.7 mμ.*

Mg ppm	Luminosity Percent	K ppm	Luminosity Percent	Na ppm	Luminosity Percent	Fe ppm	Luminosity Percent	Al ppm	Luminosity Percent
0	85.0	0	85.0	0	85.0	0	85.0	0	85.0
6	71.0	6	84.2	6	83.0	2	85.0	2	86.4
10	64.0	10	83.0	10	80.2	4	85.0	4	88.5
20	53.0	20	81.0	20	77.4	6	85.8	6	91.2
30	46.6	30	80.2	30	75.8	8	86.8	8	88.0
				100	60.3	10	87.7	10	86.2
						20	92.0	20	71.0

* All solutions contained 80 ppm Ca and the radiation buffer.
Phosphorus was not included in radiation buffer in the Fe and Al solutions because these cations would precipitate with phosphate ion.

3. Interferences from Mg, K and Na are not additive in the presence or absence of the radiation buffer (Table 4).

It is evident that it would be a practical impossibility to correct for these interferences because of their nonadditive quality. However, since the Mg ion produces the most interference a correction for Mg should give a fair approximation of the Ca concentration. This is especially true since, in the presence of the Mg ion and the phosphate-sulfate radiation buffer in solution, there is a depression in the magnitude of Na and K interferences (Table 4).

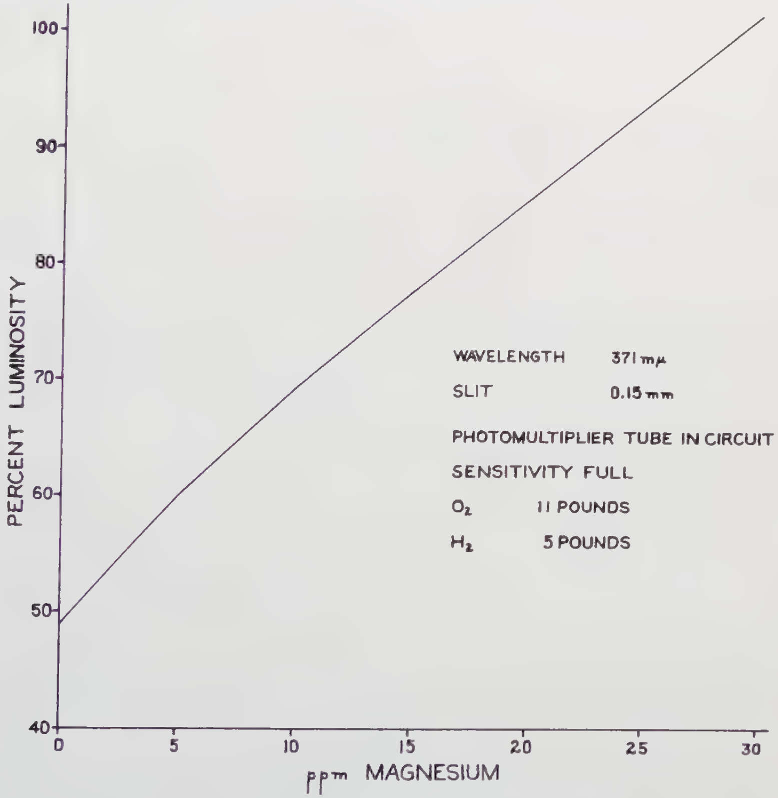

Figure 4. Standard curve for Mg containing the phosphate-sulfate radiation buffer.

Cation Interferences on Mg.—The data in Table 5 show that the interferences from all of the cations tested are positive for Mg except for Al which shows the same parabolic type interference that it does with Ca. No large differences in the amount of interference from these cations are obtained by switching from the Mg band at 371 millimicrons to the band at 383 millimicrons. According to Horn(1) many of these interferences do not appear when the Mg arc line at 285.2 millimicrons is used but the author finds that the standard curve for Mg between 0 and 30 ppm at this wavelength is too flat to be workable. Interferences from

TABLE 4.—Tests for Additive Properties of Interferences on the Ca Arc Line at 422.7 mμ.

Ca ppm	Mg ppm	K ppm	Na ppm	Radiation Buffer Present: Luminosity Percent	Radiation Buffer Present: Luminosity Expected If Interferences Were Additive—%	Radiation Buffer Absent: Luminosity Percent	Radiation Buffer Absent: Luminosity Expected If Interferences Were Additive—%
80				85.0		85.0	
80	30			46.5		74.0	
80	5			72.9			
80		30		80.3		86.3	
80			10	80.1		85.5	
80	30	30		48.3	41.8	72.0	75.3
80	5	30		69.7	68.2		
80	5		10	70.6	68.0		
80	30	30	10	47.7	36.9	71.5	75.8
80	5	30	10	69.5	63.3		
80	30		10			71.5	74.5
80		30	10			85.0	86.8

TABLE 5.—Cation Interferences with the Mg Band at 371 mμ.*

Ca ppm	Luminosity Percent	K ppm	Luminosity Percent	Na ppm	Luminosity Percent	Fe ppm	Luminosity Percent	Al ppm	Luminosity Percent
0	85.0	0	85.0	0	80.0	0	80.0	0	80.0
50	89.0	15	87.8	2	80.0	2	80.8	2	80.5
100	93.2	30	89.0	4	80.5	4	81.0	4	81.5
				10	80.9	6	82.0	6	80.6
				20	81.3	8	81.0	8	80.0
				30	82.0	10	81.0	10	79.0
				60	83.3	20	87.2	20	74.0
				100	85.3				
				300	89.2				

* All solutions contained 20 ppm Mg and the radiation buffer.

Phosphorus was not included in the radiation buffer in the Fe and Al solutions because these cations would precipitate with the phosphate ion.

TABLE 6.—Tests for Additive Properties of Interference on the Mg Line at 371 mμ.*

Mg ppm	Ca ppm	K ppm	Na ppm	Luminosity Percent	Luminousity Expected If Interferences Are Additive Percent
30				100.0	
30		30		103.2	
30			10	101.6	
30	80			105.2	
30	80	30		108.8	108.4
30	80	30	10	109.7	110.0

* All solutions contained the radiation buffer.

Fe and Al can be eliminated by precipitation with the phosphate ion added in the radiation buffer. Table 6 shows that the interferences from Ca, K and Na are remarkably additive and therefore can be corrected for, provided the concentration of these ions are known.

In all probability these interferences are from background light produced by the ionization and oxide activation of these alkali and alkaline earth metals. These interferences therefore could be decreased but not eliminated by decreasing the slit width. In order to do this it would be necessary to increase the top Mg standard or set the instrument to read the present top standard (30 ppm Mg) at some relative value lower than 100% luminosity. In so doing the range of concentrations which are likely to occur in the soil extracts would be read between a narrower range of percent luminosity values.

Methods for Correction of Interferences in the Analyses of Soil Extracts

The interferences from phosphate and sulfate ions is eliminated by the addition of a radiation buffer. This is done by transferring 10 ml of the soil extract to a 25 ml erlenmeyer flask and adding 5 ml of the radiation buffer making the extract up to at least 300 ppm P and 150 ppm S. The radiation buffer is prepared by dissolving 3.8367 grams of $(NH_4)_2HPO_4$ and 1.8547 grams of $(NH_4)_2SO_4$ in 1 liter of extracting solution. The concentration of this solution is 900 ppm P and 450 ppm S. If the soil extract contains dissolved Fe or Al in concentrations large enough to cause serious interference in the Ca and Mg determinations it will be precipitated as iron and aluminum phosphates. To prevent clogging of the capillary tube on the hydrogen burner it is necessary to refilter the extracting solution containing the radiation buffer. The filtrate is now ready to run through the flamephotometer.

Since the K reading is not affected by any of the interfering ions checked, the concentration can be determined directly. Corrections have to be made on the readings from the Ca line 422.7 millimicrons and the Mg band at 371 millimicrons. In order to do this it was necessary to produce a set of interference curves for Ca on Mg (Figure 5), for K on Mg (Figure 6) and for Mg on Ca (Figure 7). Actually these curves were made into charts to facilitate rapid correction of readings by interpolation to zero ppm of the interfering ion. Since only the concentration of K can be found with any degree of certainty it is necessary to go through a series of approximations, to obtain Ca and Mg concentrations. This is done by means of the following series of steps.

1. Correct the original Mg reading for K interference (K concentration known).

2. Determine the approximate concentration of Mg by referring to Figure 4 and using the reading obtained in step 1.

3. Correct Ca reading for Mg interference by use of the Mg concentration obtained in step 2.

4. Determine the approximate concentration of Ca by referring to Figure 3 and using the reading obtained in step 3.

5. Correct Mg reading obtained in step 1 for Ca interference using the Ca concentration obtained in step 4.

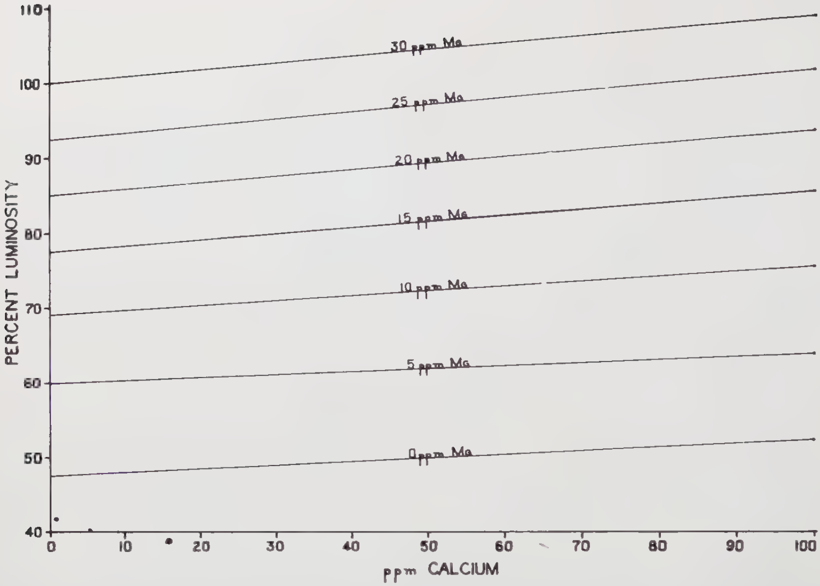

Figure 5. Correction curves for Ca intereference on Mg band (371 millimicrons).

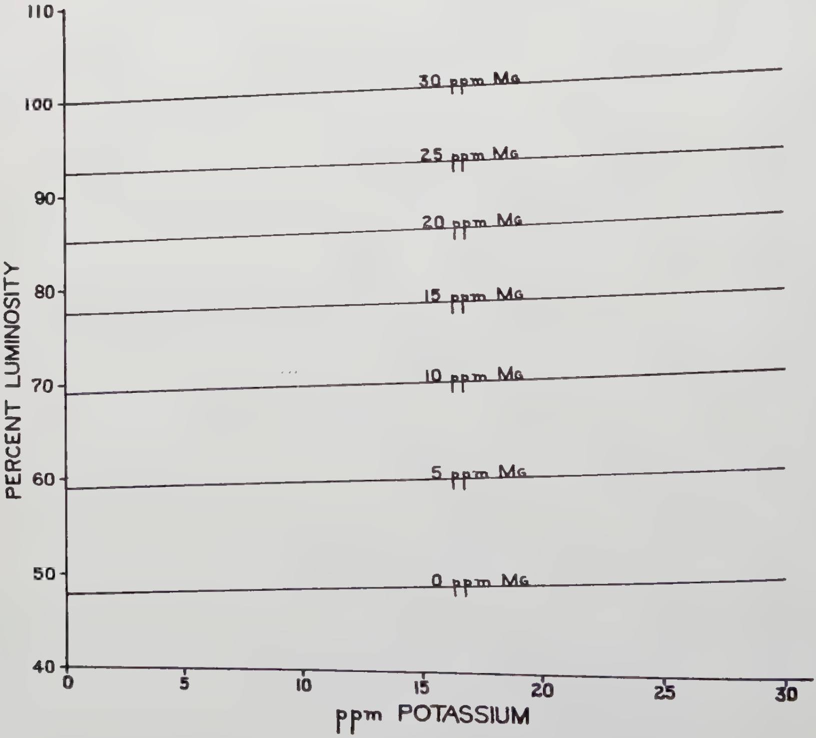

Figure 6. Correction curves for K interference on Mg band (371 millimicrons).

6. Determine the Mg concentration by referring to Figure 4, and using the reading obtained in step 5.

7. Correct the original reading obtained on Ca for Mg interference by using the Mg concentration obtained in step 6.

8. Determine the Ca concentration by referring to Figure 3, and using the corrected reading obtained in step 7.

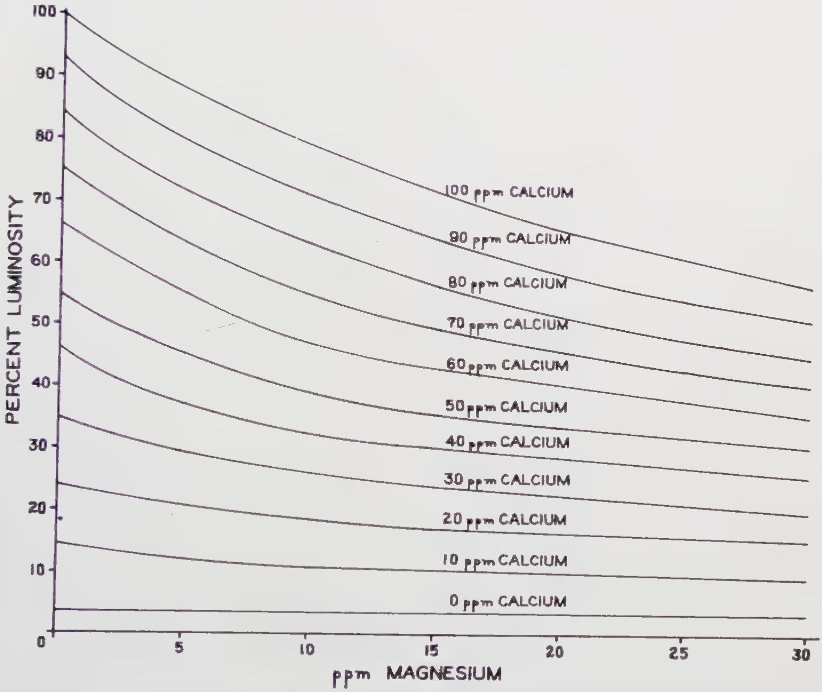

Figure 7. Correction curves for Mg interference on the Ca line (422.7 millimicrons).

Further approximations by the author were found to yield no more accurate values for Ca and Mg. The concentrations obtained in steps 6 and 8 for Mg and Ca are the final values reported.

Although it is possible to correct the Mg values further by correcting for Na interference, it was felt that the extra time involved in determining Na and making corrections for it would not compensate for the small amount of extra accuracy obtained. It can be seen in Table 5 that there is only about a 1 percent increase in the luminosity of the Mg band when the sample contains between 10 and 20 ppm of Na. This would be equivalent to 150 to 300 pounds per acre of Na. It is believed that quantities of this magnitude will seldom be found in the soils of the Gadsden County area.

CONCLUSIONS

In order to test the accuracy of the above methods of correcting for interferences, synthetic solutions were made up in extracting solution and analyzed for K, Ca and Mg. These results are shown in Table 7.

It is the author's opinion that the accuracy shown here offers a considerable improvement over a method of flame analysis of heterogeneous solutions in which no compensations are made for interferences. Only a little extra time is required after the correction charts are made up so that it is still feasible to run large numbers of farmer's soil samples in a relatively short period of time.

It can be seen that the accuracy of the Ca determinations are not all that could be asked for. This cannot be helped because as mentioned previously, the interferences on this cation are not additive. The inaccuracy in the Ca determination is not the fault of the correction made for Mg interference on Ca (Figure 7) because the samples 11 through 19 (Table 7) were in good agreement with theoretical concentrations of Ca. These latter contained only Mg as an interfering ion. In cases where more accuracy is desired (eg. research samples) it will be necessary to use more extensive and time consuming procedures.

TABLE 7.—Analyses of Synthetic Solutions for Ca, Mg and K.

Sample No.	Theoretical Concentrations in ppm								Concentrations Found by Analysis in ppm		
	Ca	Mg	K	Na	P	S	Fe	Al	Ca	Mg	K
1	80	25	10	0	6	5	10	10	87.5	25.6	10.7
2	80	15	10	0	6	5	10	10	84.8	15.9	10.5
3	80	5	10	0	6	5	10	10	83.7	6.2	10.5
4	60	15	15	3	6	5	10	10	66.2	16.5	15.5
5	60	15	10	2	6	5	10	10	65.1	15.9	10.5
6	60	15	5	1	6	5	10	10	61.5	15.3	5.3
7	40	15	5	3	6	5	10	10	48.8	16.0	5.5
8	40	10	10	2	6	5	10	10	48.0	11.5	10.4
9	40	5	15	1	6	5	10	10	47.0	6.2	15.4
11	80	25							81.1	23.5	
12	80	15							79.8	14.0	
13	80	5							78.8	4.7	
14	60	15							60.0	14.2	
15	60	15							61.9	14.5	
16	60	15							61.4	14.0	
17	40	15							40.5	14.6	
18	40	10							42.5	10.6	
19	40	5							40.2	5.1	

ACKNOWLEDGMENT

The author extends his gratitude to William B. Tappan for his aid in drawing the graphs in this paper.

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CONTRIBUTED PAPERS II

Friday, November 30, 1956—8:30 A.M.
Earl G. Rodgers,* Moderator

Volatility and Drift of 2,4-D As a Cause of Damage to Untreated Sensitive Plants

Victor L. Guzman **

INTRODUCTION

The use of 2.4-D for weed killing purposes has been followed in some cases by damage to sensitive crops growing in the vicinity of the treated area and a few times at distances of a mile or more from the sprayed field. Drift or volatility of the 2.4-D material, or both, have been blamed for the damage. In an effort to prevent or minimize this tendency through a knowledge of the factors involved, a series of experiments was initiated in 1952 to find, 1) what differences if any existed among the various 2,4-D formulations in their volatility, 2) the influence of temperature and wind turbulence on volatility, and 3) the importance of these factors under field conditions in causing contamination of untreated sensitive plants.

MATERIALS AND METHODS

"Phytotoxic volatility" or "volatility" as used here is the reaction of tomato plants to 2,4-D vapors. The degree of "phytotoxic volatility" may or may not be related to the actual amount of material evaporated, since a more herbicidally potent compound, although it evaporates less, may produce a more severe reaction. Drift and volatility were measured by growth response and by their effect on yield and quality of the tomato fruit. The Rutgers variety was used throughout these studies. Plots were laid out in randomized blocks and 4 to 10 replications were utilized.

1. *Effect of 2,4-D Under Confined Atmosphere.*—Tomato plants five weeks of age were placed in stoneware crocks with glass covers and/or paper bags (bell jar experiments) for a 12 and/or 24 hour period together with ten cc. of the 2,4-D compound in a petri dish. Ten replications were used per treatment in three experiments.

2. *Effect of Air Turbulence and Temperature on the Volatility of Dimethylamine Salt of 2,4-D.*—Corn plants were heavily sprayed with a solution of dimethylamine of 2,4-D at the concentration of two pounds of acid equivalent in 30 gallons of water. As soon as the leaves were dry the plants were moved to one corner of the chamber (Fig. 1), diagonally opposite the eight weeks old tomato plants. A fan located between the two sets of plants pulled air from the corn toward the tomatoes for a 12-hour period.

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Three chambers were equipped to provide temperatures of 20°, 27° and 40° C. and wind velocities of 5, 8 and 12 m.p.h., so that nine treatments were obtained from the various combinations. Check plants (without treatment) were provided for each set of experiments. Ten replications per treatment were used.

Temperatures were recorded continuously during treatment. Height of the plants was measured two weeks after treatment.

The experiment was begun March 31, 1952; the plants were measured April 17 and harvested from June 6 to July 17.

Figure 1.—Chamber used for controlled temperature and wind turbulence studies.

3. *Drift and Volatility Studies under Field Conditions Using a Low-volatile-ester and an Amine Salt of 2,4-D.*—Eight weeks old tomato plants growing in cans were placed, prior to spraying, in rows at various distances from the edge of two recently cut cane fields which were spaced one-fifth of a mile apart. This was called the drift series, since the

response of the plants would show the effect of drift of 2,4-D during the spraying operation that followed. Immediately after spraying, the plants were collected and another series of tomato plants were placed for 24 hours in similar position in the fields in an attempt to determine, by their response, the effect of volatility of the 2,4-D compounds after spraying. Precautions were taken to avoid contamination of the volatility series plants with the plants already exposed to drift. A low-volatile-ester and the dimethylamine salt of 2,4-D were sprayed in field 1 and 2, respectively, at the rate of 2 lbs./A. in 75 gallons of water. The spraying was done by a power rig at 50 p.s.i. covering a 15 foot swath beginning in the middle of the cane field and progressing southward; meanwhile the rows of tomato plants were located on the north half of the field parallel to the direction of travel of the spray rig. In the ester field the tomato plants were placed at 40, 120 and 250 feet from the edge of the sprayed area. In the amine field the tomato plants were placed at 50, 150, 350 and 800 feet from the edge of the sprayed area. The cane fields were of such size and form that it was impossible to duplicate these distances without introducing other modifying factors.

The spraying operation began at 6:00 A.M. with the butoxy ethanol ester of 2,4-D and ended at 1:30 P.M. with the dimethylamine salt of 2,4-D. At 6:00 A.M. the wind velocity was practically nil, increasing to 3 m.p.h. at 8:00 A.M. and thereafter during the spraying of the ester. The dimethylamine of 2,4-D was sprayed from 10:00 A.M. to 1:30 P.M. At 10:00 A.M. the wind had increased to 8 m.p.h. The average wind velocity from 10:00 to 10:15 was 15 m.p.h. with a maximum of 20 m.p.h. and a minimum of 5 m.p.h. During the experiment the wind was in a SSE direction blowing toward the test plants.

The air temperature from 6:00 to 8:00 A.M. (time of spraying the butoxy ethanol ester) was approximately 70° F. The air temperature increased rapidly from 80° F. at 10:00 A.M. to 95° F. at 1:00 P.M. Likewise the temperature of the uppermost layer of soil increased from 62° F. at 6:00 A.M. to 107° F at 1:00 P.M.

RESULTS

1. Plants treated with propylene glycol, butoxy ethanol and isopropyl esters in the bell jar experiments showed bending of the stem at the end of the 24 hour period (Fig. 2). Other symptoms of severe 2,4-D injury appeared later. The plants of the isopropyl treatment developed the most chlorotic condition, became proliferated and formed stem cankers. At the end of three weeks most of them were dead. Plants treated with propylene glycol and butoxy ethanol esters tended to recover and, although they were severely injured, all plants remained alive. Plants treated with the sodium salt, dimethylamine salt (prepared in the laboratories of the U. S. Sugar Corporation) and alkalonamine salt of 2,4-D remained normal (Fig. 2). A few plants treated with dimethylamine and diethanolamine salts of 2,4-D were bent slightly.

The average reaction of the test plants to vapors of several 2,4-D compounds in the bell jar experiments are shown in Table 1. The isopropyl ester of 2,4-D was extremely volatile at temperatures of 60° F. or over. Its injurious effect was more severe as the temperature increased.

TABLE 1.—Symptomatic Reaction of Tomato Plants When Exposed to Vapors of Several 2,4-D Compounds in a Confined Atmosphere.

Form of 2,4-D Used	Type of Reaction on the Stems *		
	Curvature	Proliferation	Canker Formation
Check	0	0	0
Sodium salt	0	0	0
Dimethylamine salt	traces	0	0
Dimethylamine salt †	0	0	0
Alkalonamine salt	0	0	0
Diethanolamine salt	traces	0	0
Butoxy ethanol ester	**	**	**
Propylene glycol ester	***	**	**
Isopropyl ester	****	****	****

* Zero no response; ** light; *** moderate; **** severe response.
† Prepared in the research laboratory of the United States Sugar Corp., Clewiston.

TABLE 2.—Relative Growth of Tomato Plants 15 Days After Exposure When Treated with Various 2,4-D Compounds, Expressed as Percentage of the Check Growth.

	Percent of Check
Experiment II	
Check	100
Sodium salt	104.3
Dimethylamine salt	97.3
Dimethylamine salt (U.S.S.C.)	89.5
Alkalonamine salt	99.1
Propylene glycol ester	62.3
Isopropyl ester	60.5
L.S.D. .05	21.8
Experiment III	
Check	100
Sodium salt	95.8
Dimethylamine salt	96.1
Isopropyl ester	26.7
L.S.D. .05	5.6

TABLE 3.—Sum of the Angle of Deviation of Ten Tomato Plants from a Normally Erect or Straight Growth Expressed as Percentage of the Check.

Treatments	Percent of Check
Check	100
Sodium salt	147
Dimethylamine salt	204
Dimethylamine salt (U.S.S.C.)	104
Alkalonamine salt	183
Propylene glycol ester	2087
Isopropyl ester	4369
L.S.D. .05	171.0

Butoxy ethanol and propylene glycol esters were almost non-volatile at temperatures below 70° F. As the temperature increased, however, volatility increased.

Fifteen days after treatment plants treated with the propylene glycol and isopropyl esters were stunted (Table 2). The isopropyl ester treated plants were the more seriously affected.

Figure 2.—Plant at right was injured by the vapors of propylene glycol ester and the second from right by isopropyl ester. Check plant is in center. Plants at left show no reaction to treatment with the sodium and dimethylamine salts of 2,4-D.

The degree of stem curvature (angle of deviation from a normally erect stem considering a straight stem as zero) in plants of Experiment II, is given in Table 3. The larger the deviation from a straight line the greater was assumed to be the effect of the treatment. The angles of deviation gave results similar to those observed in gain in growth (Table 2). There was a significant difference between the degree of stem curvature caused by either propylene glycol or the isopropyl ester treatments and that caused by any other treatment.

There was no significant difference in yields of the plants treated with the sodium and dimethylamine salts of 2,4-D and the check plants (Table 4). This seems to indicate that these salts have a sufficiently low vapor pressure to be inactive or non-phytotoxic volatile under the conditions studied. Plants treated with the isopropyl ester died. The quality and general appearance of the fruits of the treated plants were similar to those of the check.

The results of the bell jar studies indicate that the esters of 2,4-D are volatile, the isopropyl form being much more so than the propylene glycol and butoxy ethanol. The amine and sodium salt formulations appeared to be non-phytotoxic volatile at temperatures as high as 103° F.

TABLE 4.—YIELD IN POUNDS OF FRUIT FROM PLANTS EXPOSED TO VAPORS OF 2,4-D.

Treatments	U. S. 1's	Total Marketable
Check	232.2	320.2
Sodium salt	225.3	304.2
Dimethylamine salt	241.0	332.0
L.S.D. .05	N.S.	N.S.

2. Symptom severity at the end of a 12-hour period showed a straight line relationship between wind and temperature under controlled conditions in the chambers. The tomato plants treated at low temperature and low wind velocity showed practically no symptoms of 2,4-D injury. Plants treated at high temperature and high wind velocity showed twisting and bending of the stem. The intermediate treatments revealed intermediate and varied degrees of injury positively correlated to both factors according to their intensity (Figs. 3 and 4). These symptoms diminished soon after transplanting. Light 2,4-D injury continued to manifest itself, however, in the new leaves which developed a few days after transplanting. In most cases these symptoms appeared in the plants treated at high temperature and high wind velocity. All leaf malformations disappeared in the course of two weeks. At high wind velocity and high temperature the increase in height of the plants was significantly less than the corresponding values in the check plants. At low wind velocity and low temperatures the increase in height was significantly greater than in the check plants (Table 5).

TABLE 5.—GAIN IN HEIGHT OF TOMATO PLANTS EXPOSED TO THE ACTION OF 2,4-D AT THREE DIFFERENT LEVELS OF TEMPERATURE AND WIND TURBULENCE EXPRESSED AS PERCENTAGE OF THE CHECK.

Wind Velocities (m.p.h.)	Temperatures (C°)			Totals	L.S.D. (5%)
	40	27	20		
12	61.34	139.17	123.71	324.22	8.03
8	90.66	121.33	120.00	331.99	24.32
5	106.79	150.48	148.54	405.81	14.73
Totals	258.79	410.98	392.25		

There was no significant difference in yields due to treatments under the conditions involved. The fact that the soil was heavily infested by nematodes which caused the death of many plants after the first or second picking of the fruit probably was involved.

Some of the first fruits in some plants were slightly elongated, but there was not a consistent correlation between elongated fruit shape and the intensity of wind or degree of temperature. There also appeared

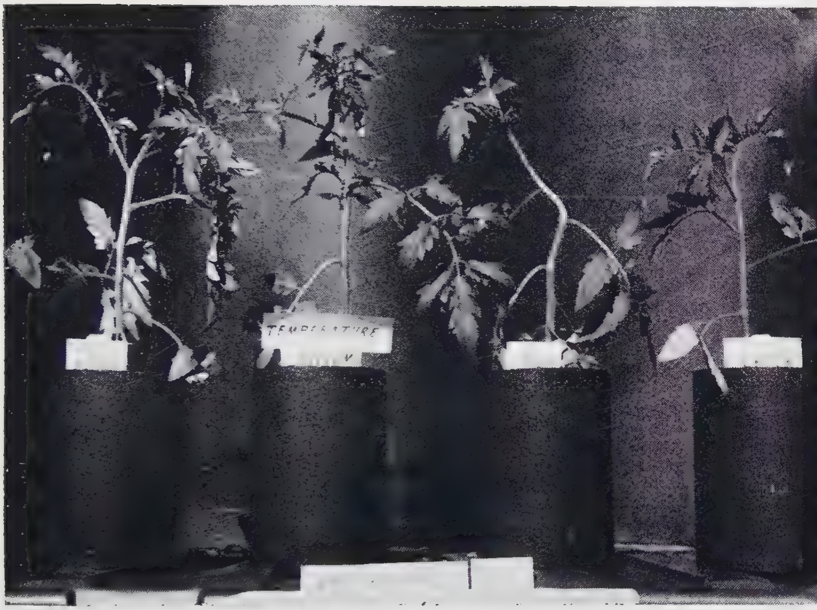

Figure 3.—Effect of 2,4-D at low wind turbulence and three temperatures on tomato plants. At 20°C. (low) and 27°C. (medium) almost no reaction occurred. At 40°C. (high) the stem was bent. Check plant at the extreme right.

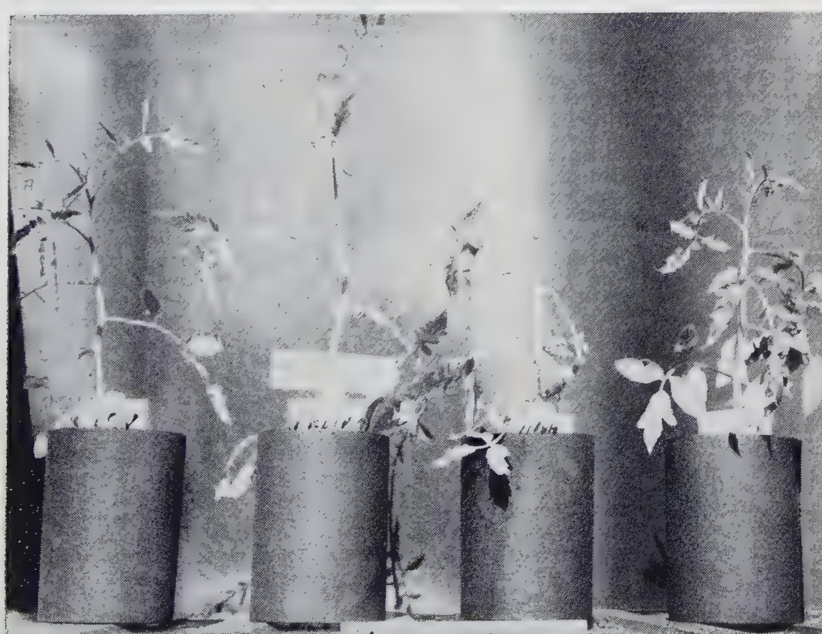

Figure 4.—Effect of 2.4-D at high wind turbulence and three temperatures. At 20°C. (low) and 27°C. (medium) some reaction is shown, mostly on the leaves. At 40°C. (high) the stem was severely bent. Plant at the right is the check.

to be a tendency for the fruit of damaged plants to have an oversized, hard, fibrous core. However, the relationship of this symptom to treatment should be considered strictly tentative until more data are secured.

3. In experiments under field conditions the stems of the drift series tomato plants treated with butoxy ethanol ester showed no curvature. Plants in the 120-foot row in this test also displayed slight bending of the stems. Stems of the other plants remained normal.

Leaves of four plants in the 40 foot row of the butoxy ethanol ester drift series showed typical 2,4-D symptoms. The leaves of a few plants in the 120 foot row also appeared to be slightly affected. Leaves of the plants in the 250 foot row remained normal. Fruits of two plants in the 40 foot row were pear-shaped. Fruits of plants in the 120 and 250 foot rows were normal.

In the volatility series of the butoxy ethanol ester plants in the 40-foot row showed severe bending and twisting of the stems at the end of the 24-hour exposure. The leaves of the plants in the 40-foot row, contrary to expectations, presented no conspicuous effects due to 2,4-D. A few plants in the 120 foot row showed some effect of 2,4-D action. The leaves of plants in the 250 foot row showed very slight reaction to the ester. There appeared to be a slight retardation in growth and flower production in plants in the 40 and 120 foot rows. Fruits of three plants in the 40 foot row, two in the 120 row and three in the 250 foot row were pear-shaped and smaller than those of the check plants. The pear shaped fruits were most elongated in the 40 foot row plants, less elongated in the 120 foot ones, and only slightly affected in the 250 foot row.

The stems of the tomato plants in the 50 foot row of the drift series of the dimethylamine of 2,4-D test showed a severe bending but not as much as did those in the 40 foot row of the volatility series using the ester formulation. Fifteen days after treatment the plants in the 150 foot row and some in the 350 foot row showed a very slight bending of the upper part of the stems. Plants in the 800 foot row remained normal.

In the drift series of the dimethylamine treatment there was a very light malformation of the tomato leaves in the 50 foot row. A few plants in the 150 and 350 foot rows showed a very mild leaf malformation. Tomato plants in the 50 foot row seemed to be slightly retarded in growth and in flower production. About one-third of them produced a few pear-shaped fruits. Usually the first cluster of fruits was pear-shaped. Plants in the 150, 350 and 800 foot rows had normal flowers and fruits.

The stems of plants in the 50 foot row of the dimethylamine salt volatility series showed very slight bending. No 2,4-D effect could be detected in the plants in the other rows. Fifteen days after treatment plants in the 50 foot row still showed slight bending of the upper stems. Plants in the 150 to 800 foot rows remained normal.

In the volatility series of the dimethylamine salt a few plants in the 50 foot row showed a tendency to have small young leaves but they were not typical of 2,4-D damage. Flower and fruit production was normal in all plants of this series. Table 6 gives the gain in growth of ten tomato plants during 15 days following treatment.

Although the wind velocity was unusually high at the time of spraying the amine salt, only the 50 foot row plants were affected by drift

of the material. Plants in the 50 foot row were significantly shorter than those in the 150, 350, 800 foot rows or the check plants.

TABLE 6.—Effect on Gain in Height of Tomato Plants Exposed at Various Distances from the Sprayed Area of Drift and/or Volatility of Dimethlamine Salt of 2,4-D Fifteen Days After Treatment.

Feet from Sprayed Area	Height in Centimeters	
	Drift	Volatility
50	27.0	45.5
150	49.5	45.5
350	55.0	54.5
800	57.0	44.5
Check	51.0	51.0
L.S.D. .05	8.03	N.S.

There was no significant difference in yields among plants of the different treatments and their checks. This might be partially accounted for by the presence of a severe nematode infestation that killed many of the plants after the second picking. The flavor and color of the fruits were normal, although many of them, including the fruits of the check plants, had a hard undesirable core. Whether this condition was due to severe drought, to nematode infestation or both was not determined.

DISCUSSION

1. There was a correlation in the bell jar studies between degree of damage by 2,4-D to the plants whether measured by rate of growth or by the amount of stem curvature. Variation within each treatment when measured by angular deviations in the stems was greater than in the case of the rate of growth. This is shown by comparison of the L.S.D.'s, which for growth was 21.8 and for angular deviations 171.0. This latter measurement of 2,4-D action seemed to be more sensitive than the gain of growth for the plants treated with the isopropyl ester of 2,4-D. The same trend is apparent for the plants treated with propylene glycol ester of 2,4-D.

2. The rate of growth of tomato plants exposed to 2,4-D at 40° C. appeared to be decreased in the chamber experiments (Table 5, totals for temperatures). This might be due in part to higher 2,4-D concentration in the 40° C. chamber since relatively more chemical is required to saturate a given atmosphere at higher temperatures than at lower ones. High temperatures also increase membrane permeability, osmosis, translocation, etc., which might have caused absorption of 2,4-D in toxic amount and growth inhibition as a consequence. At 27° C. and 20° C. the amount of 2,4-D absorbed appeared to be just enough to produce a stimulation in the rate of growth.

Wind turbulence within the chamber influenced the effect of 2,4-D on the tomato plants, probably by increasing the rate of volatilization, stirring the air and maintaining the steepness of the vapor gradient of

the chemical in the surrounding air at its maximum. It seems that after the vapor gradient reaches equilibrium in the chamber, wind velocity should be a minor factor. At high wind velocities it is probable that the air in the chamber became saturated with 2,4-D in a shorter time. Thus the tomato plants were subjected to the maximum 2,4-D concentration for a longer period. It is also possible that the 2,4-D symptoms manifested by the tomato plants were caused by drift of 2,4-D particles, or minute dust particles contaminated with 2,4-D which were present on the leaves of the corn plants at the time of spraying. The influence of wind velocity on symptom severity, however, appears to be less important than temperature.

It is difficult to say how much of the information obtained in this work could be useful in predicting possible damage to untreated crops under field conditions. The 2,4-D salt seems sufficiently volatile at high temperatures so that plants located adjacent to the sprayed area probably would show some 2,4-D effect under very low air movement conditions. If the air were appreciably in motion, equilibrium could never be reached under field conditions since the atmosphere is so vast that dilution to extremely low concentration is rapidly accomplished. Under these conditions damage to untreated susceptible plants due to volatility of dimethylamine of 2,4-D would be highly improbable.

3. In experiments in the field tomato plants of the drift series were practically unaffected by the ester, since the wind velocity at spraying time was very low, and drift was at a minimum. The volatility series plants, on the other hand, showed a severe reaction to 2,4-D in the 40 and 120 foot rows. Wind velocity and temperature of the air and soil increased greatly during part of the 24 hour exposure of the plants in the volatility series. The reaction of the plants was probably due to the combined effect of the vapors of the ester and drift of 2,4-D contaminated dust particles blown by the wind during the 24-hour exposure. Volatilization of the ester was probably increased by the high temperature of the air and upper layer of soil (95° F. and 105° F. at 1.00 P.M. for air and soil respectively).

The fact that the plants of the volatility series of the butoxy ethanol ester of 2,4-D showed a much more marked effect than plants of the volatility series of dimethylamine of 2,4-D indicates that the former compound gives off toxic vapors of enough strength or in sufficient amount to cause a reaction in the tomato plants. The reaction of plants in the ester volatility series could be due in part to drift of dust particles contaminated with the herbicide from the sprayed field. If this latter assumption is correct it should also be true for the plants of the amine series, since the wind velocity was relatively high after spraying. If the drift of contaminated dust were the only cause of the toxic reaction of the ester treated plants, the plants of the amine volatility series probably would have been damaged in similar manner. Since this was not the case, the results indicate that the ester form is more volatile than the amine salt of 2,4-D.

Retardation of flower production and the appearance of elongated fruits also were much more pronounced in the ester treated plants than in the amine ones, whether the plants belonged to the drift or volatility series. It is worth noting, in relation to both drift and volatility of the

dimethylamine of 2,4-D, that only the plants in the 50-foot row showed a tendency to produce pear-shaped fruits.

SUMMARY

Studies were made to find the factors which affect drift or volatility of 2,4-D under laboratory and field conditions in order to avoid injury to susceptible plants grown in the vicinity of the sprayed area.

1. When tomato plants were exposed in confined atmosphere (bell jar experiments) to various 2,4-D compounds it was found that the salts of 2,4-D are not volatile at temperatures as high as 103° F. The propylene glycol and the butoxy ethanol low-volatility esters are volatile at 75° F. or higher and the isopropyl ester of 2,4-D is highly volatile at temperatures from 60 - 103° F.

2. When tomato plants were exposed in large chambers to the effect of dimethylamine of 2,4-D it was found that the plants exposed at 20° F. and wind 5 m.p.h. showed practically no symptoms of 2,4-D injury. Plants treated at 40° C. and 12 m.p.h. wind showed twisting and bending of the stem. The intermediate treatments revealed various degrees of injury positively correlated to the intensity of the factors under study. Most symptoms, however, disappeared two weeks after transplanting.

High temperature and high wind velocity decreased the rate of growth of the tomato plants significantly from the check (a retarding effect). At low wind velocity and low temperature the increase in height of the plants was significantly greater than in the check plants (a stimulating reaction). It seems that high temperatures and wind velocity caused a temporary stunting of the tomato plants which could be attributed in part to damage of the 2,4-D vapors. There was no significant difference in yields due to treatments, however.

3. When tomato plants were exposed to drift and volatility under field conditions it was found that drift appeared to be the only factor responsible for damage to the tomato plants when using the 2,4-D amine salt. An average wind of 10.2 m.p.h. is enough to cause a reaction in tomato plants 350 feet from the sprayed area.

Although drift may cause damage to susceptible plants when using the butoxy ethanol low volatile ester of 2,4-D, volatility of the material also seems important.

High temperature appeared to volatilize the ester as measured by the response of the tomato plants. Similar conditions seemed to cause no measurable damage to the corresponding plants of the amine treatments.

Under the conditions of this experiment, butoxy ethanol ester of 2,4-D appeared to be "phytotoxic volatile". Dimethylamine of 2,4-D under the same conditions seemed to be "non-phytotoxic volatile".

ACKNOWLEDGMENT

Acknowledgment is due Mr. B. W. Hundertmark, agronomist of the United States Sugar Corporation Research Laboratory, who was in charge of spraying operations in the field.

Effect of Several Herbicides on Pasture Grasses

J. E. McCaleb and D. W. Jones

The development of chemical weed control offers many intriguing opportunities to those interested in agriculture. Many trials have been made of the effect of herbicides on broadleaf weeds and grasses of the annual type. However, little information is available regarding the effect of these chemicals on the important pasture grasses grown on the sandy soils of peninsular Florida. If the commonly used definition that "a weed is a plant out of place" is true, then pangolagrass, bahiagrass and many other grasses may be undesirable plants in some situations. Information leading to the control or eradication of these grasses is necessary.

Trials with certain chemical weed killers on perennial grasses were started in May, 1956 with three objectives in mind: (1) determination of the response of selected pasture grasses to different chemicals; (2) measurement of the rate in pounds of active ingredients required per acre to eradicate each species with one treatment; (3) development of information and methods of control which can be used in pasture management.

Herbicides were applied in May and October, 1956 with boom type spray equipment, using No. 18 Spray Systems (TeeJet) nozzles at 30 psi. Approximately fifty gallons of water per acre were used as a carrier in all trials. The first trial was on an area which had been mowed to a height of four inches previous to chemical treatment. Seven herbicides were applied to unreplicated plots 10 x 90 feet in size. All chemicals were used at three rates, resulting in 21 plots, each plot receiving one treatment. The herbicides and pounds of active ingredients per acre used in this trial and the average results obtained are shown in Table 1.

The chemicals used in the October, 1956 trial were applied to plots 6 x 30 feet in size. The five herbicides which were used at three rates with three replications of each rate and the average results obtained are shown in Table 2.

RESULTS AND DISCUSSION

The average effect of several herbicides on selected pasture grasses, shown in Table 1 and Table 2 cannot be compared directly due to variations in amounts of chemicals applied. Different dates of applications may also influence the results.

The herbicides containing Dalapon appear to be most effective on all grasses studied. However, other materials such as amino triazole and TCA seem to be more selective and offer possibilities where two or more species are involved. CMU shows little selectivity, but is an effective general plant killer when applied at high rates. 2,4,5-T has few possibilities for grass control even at the highest amounts used in

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these trials. The herbicidal action of Erbon appears to be similar to Dalapon with the possible exception of lowered activity on some species.

The trials to determine the effect of herbicides on selected grasses are too limited in number and length of time to be conclusive enough to make recommendations. However, the information does present possibilities for further work in the control or eradication of these species.

TABLE 1.—Average Effect of Herbicidal Treatment on Five Pasture Grasses, May 24, 1956.

	Pounds of Active Ingredients per Acre	Bermuda	Smut	Pangola	Carpet	Bahia
Dalapon *	12.75	2.75**	7.25	1.25	7.75	4.75
	21.25	5.50	8.50	3.25	8.50	7.50
	34.00	6.50	7.25	4.00	8.75	8.25
TCA	18.00	3.00	2.50	1.75	6.25	1 50
	36.00	4.00	6.75	4.25	6.25	3.25
	54.00	4.25	8.75	4.50	7.00	6.25
CMU	16.80	5.75	7.50	5 00	8.75	8.50
	33.60	8.75	9.25	8.75	9.25	9.25
	50.40	9.50	10.00	10.00	10.00	10.00
Dalapon + Amino Triazole	6.38 2.50	4.50	5.00	3.00	6.25	3.75
	10.60 5.00	5.50	7.00	4 25	6.25	5.75
	17.00 7.50	5.50	8.50	5.25	7.50	6.25
Erbon	40.00	4.50	5.00	4.75	7.00	5.25
	80.00	6.75	6.00	5.75	7.50	6.50
	120.00	7.75	6.50	6.25	8 25	9.00
2,4,5-T	5.00	1.00	1.25	.50	.75	.50
	10.00	2.00	1.25	.50	.75	.50
	15.00	1.00	.75	.75	2.25	.50
Amino Triazole	5.00	3.25	.75	.50	.50	.50
	10.00	5.00	.75	.50	.50	.50
	15.00	8.25	1.00	.25	2.25	.75

* Technical names of all chemicals in appendix.
** 0 = No effect.
10 = Complete kill.

APPENDIX

Dalapon .... 2,2-dichloropropionic acid
TCA .... Sodium trichloroacetic acid
CMU (Karmex W) .. 3-(p-chlorophenyl)-1,1-dimethylurea
Erbon .... 2-(2,4,5-trichlorophenoxy)-ethyl-2,2-dichloropropionate
2,4,5-T .... 2,4,5-Trichlorophenoxyacetic acid, propylene glycol butyl ether ester
Amino triazole 3-amino-1,2,4-triazole

TABLE 2.—Average Effect of Herbicides on Selected Grasses, October 5, 1956.

	Pounds of Active Ingredients per Acre														
	Dalapon			T C A			C M U			Erbon			Amino Triazole		
	15	30	45	20	40	60	5	10	15	40	80	120	5	10	15
Pangolagrass	6.1	7.5	8.4	4.9	6.4	6.4	2.0	2.0	3.9	6.7	6.9	7.4	4.2	5.0	5.4
Common Bahiagrass	6.2	7.4	7.8	2.2	2.5	3.4	1 8	2.5	3.0	4.4	4.7	6.7	1.2	1.2	1.7
Smut Grass	3.5	4.2	4.5	3.1	4.0	3.9	1.5	2.2	3.8	3.2	2.8	3.4	1.0	1.5	1.0
Carpet Grass	8.4	8.5	8.8	5.8	8.0	8 8	1.5	2.8	2.8	3.8	5.5	7.5	4.5	6.3	6.3
Pensacola Bahiagrass		6.5	6.5	1.5	2.0	3.5	1.0	1.0	1.0	1.0	2.0	4.5	1.5	1.5	2.0
Torpedo Grass	6.0	6.0	6.2	4.0	4.4	4.4	0 0	0 5	1.0	3.2	4.2	5.2	3.0	3.5	4.5
Common Bermudagrass	5.5	5.5	7.5	5.5	6 0	6.5	2.0	1.5	2.5	6.0	6.5	6.5	5.0	6.0	6.0
Coastal Bermudagrass	5.3	5.7	6.8	3.0	4.5	5.0	1.0	1.0	1.8	4.8	6.3	6.0	3.8	4.3	3.5

Weed Control Problems in Florida Citrus Groves

W. A. Simanton and John R. King *

Weeds grow as abundantly in most Florida citrus groves as they do on other agricultural lands. Many of these plants serve as cover crops and hence are not in the category of unwanted vegetation. Clean cultivation is not the goal, because cover crop plants are necessary to maintain the organic matter in the light sandy soils used as grovelands. Weeds that can be readily controlled by the usual grove practices are of little concern other than as natural cover crops. Of over a hundred species of plants commonly occurring in groves, only about 30 species are undesirable. Of these, perhaps 20 can become serious pests as evidenced by the trouble and expense they are now causing in some areas. This paper discusses a number of the general weed problems and some that are more restricted in area but are serious where they occur.

Troublesome weeds have always existed in grove lands, but for the most part they have been successfully controlled by the usual cultivation practices supplemented by the man with the hoe. Two things have altered the situation in recent years: first is the inherent nature of certain rank-growing plants to spread out over more land or to become readily established in new areas where they have been carried. Where such plants possess the ability to put forth vigorous growth despite the usual cultural operations, they have become pest weeds. Another factor is that higher costs for mechanical operations as well as for hand labor limit the effort that can be economically justified in combatting weeds. Not to be overlooked is the expansion of citrus plantings into pasture lands, and close to lowlands and ditches where persistent and rank-growing plants are established.

The weeds specifically mentioned later in this paper are the ones that have become pests despite good grove care. There is good reason to believe they will become more noxious unless given special attention both by research men and by growers.

Research specifically for the purpose of finding better ways to combat weeds in citrus groves has not been carried on extensively in Florida. In 1946 T. W. Young(1) reported his investigation of 2,4-D compounds for the control of balsamapple (*Momordica* sp.) and other broadleaf weeds in groves. He found the 2,4-D herbicides to be effective when repeated applications were made, but recognized that injury to citrus might result. Reitz and Long(2) reported on experiments conducted in East Coast groves in 1953 in which aromatic oils at 200 gallons per acre were found to be of some value in suppressing guineagrass and paragrass. None of the results to date have been conclusive enough to justify recommendations. In California, weed control practices using herbicidal chemicals and aromatic oils have been adopted during the past 10 years. In general, the methods devised for California groves do not

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appear suited to Florida conditions, largely because of the greater rainfall and its seasonal distribution in this state.

Several weed control experiments are now under way by members of the Citrus Station staff. As these studies progress it is hoped that sufficient information will be obtained to permit control recommendations to be issued.

One phase of the current research, that of determining the weed problems that exist in groves, has progressed to the point where a report can be made. The information presented here resulted from the authors' own observations and from questionnaires returned by 45 citrus production managers and 20 county agents representing all citrus areas of the state. Weed problems fall into rather distinct groupings whether based on land use or on some similarity of the weeds themselves. Thus each of these several groupings is presented and discussed.

Grasses.—The grass family appears to constitute the most important group of grove weeds, one or another species appearing in the "important" category 101 times in the survey data.

Bermudagrass (*Cynodon dactylon* (L.) Pers.) was listed 18 times. It occurs commonly in most groves over the state, thriving particularly on heavier soils. While many growers consider this low-growing grass as a cover crop, and in some cases as a soil-holding medium, established vigorous stands do compete with citrus trees and ordinary tillage does little to eliminate it.

Maidencane (*Panicum hemitomon* Schult), listed 16 times, is frequent in Central Florida, often creeping in from lakeshores, swamps and ditches.

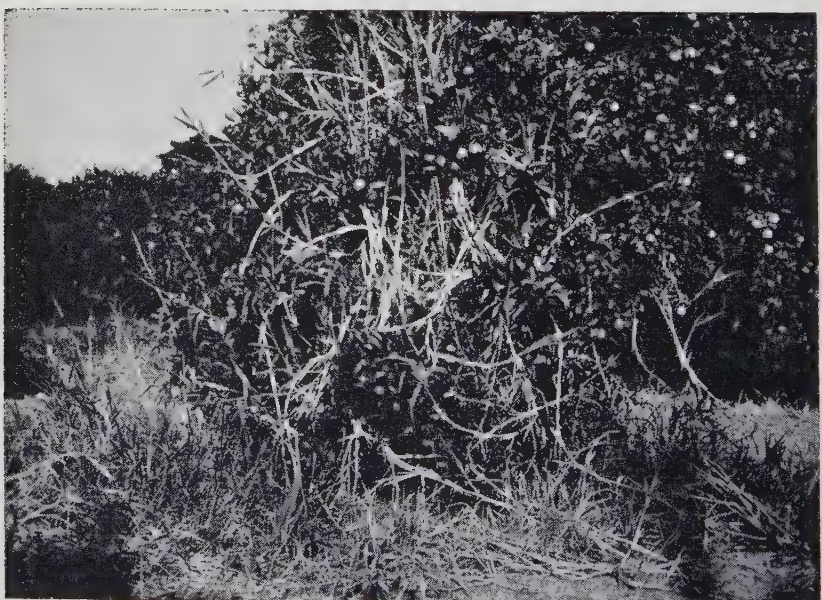

Figure 1. Maidencane twining through an orange tree.

This grass can spread rapidly by elongation and rooting of the culms or canes. It grows up through trees, shutting out sunlight, forming a bridge for insects and vines, and also competing for moisture. Tillage cuts the canes but does not destroy the major root system. Hand work is required to remove the tall canes from trees (Figure 1).

Paragrass (*Panicum purpurascens* Raddi), also listed 16 times, produces a dense and tall vinelike growth much as does maidencane. It is generally the most serious problem in the coastal areas.

Figure 2. Guineagrass almost obscuring the young replant tree in center of the photograph.

Figure 3. Torpedograss extending from the pasture (foreground) into a lime grove despite frequent discing of the grove (center). Middles at left and right were treated with herbicides.

Guineagrass (*Panicum maximum* Jacq.), mentioned as important 15 times, grows in tall clumps, often one to two feet across at the base and five to seven feet tall. It is rather common in coastal groves and has become a problem in a number of interior areas as well. Where allowed to become established, neither mowing nor discing does more than retard it temporarily. An infestation by guineagrass is illustrated in Figure 2.

Pangola grass or Spreading Crabgrass (*Digitaria decumbens* Stent.) and Torpedo Panicum (*Panicum repens* L.) are two pasture grasses that are a very serious problem in groves planted on former pastures or adjacent to stands of these persistent and aggressive grasses. Figure 3 portrays a torpedograss problem in a lime grove.

Napiergrass, Johnsongrass, Signalgrass, Natalgrass and Cogongrass are among other species that less frequently are encountered as pests. Nutgrass is a general problem but is generally considered of major importance only in nurseries.

VINES.—These make up the second most important group, having been listed 62 times in the survey data. The vine group is especially troublesome in old groves, being particularly abundant in the outside rows adjacent to lowlands, ditches, culverts and fence rows. Vines not only have a smothering effect on the trees but interfere with spraying, pruning and picking operations. They serve as ladders for insects, and some, such as the citronmelon, act as hosts for citrus pests.

Balsampear (*Momordica charantia* L.), also known as stinkvine and wild cucumber, is common in groves throughout the state. The ability

of this fast-growing vine to reseed itself readily and to defy control even by frequent hoeing classifies it as a major pest.

Maypop Passionflower (*Passiflora incarnata* L.) is considered nearly as common and troublesome as balsamapple. It also reseeds readily and defies control by cultivation.

Rosarypea (*Abrus abrus* L.), commonly called crab's eye and sometimes blackeyed Susan, is a tough-stemmed vine that also reseeds readily. Figure 4 shows *Abrus* vine infesting a mature orange tree.

Figure 4. *Abrus* vine in top of orange tree. Polkberry is emerging and fruiting through the top on the left side. Bermudagrass in foreground had been disced one hour before this photograph was made.

Frost Grape (*Vitis vulpina* L.), the common wild grapevine, is a pest in trees adjacent to uncultivated areas but seldom is troublesome inside the grove.

Citronmelon (*Citrullus vulgaris-citroides* Schrad.) is a problem in young groves on sandy soil in the central part of Florida. While this plant is not a high climber, the vines and particularly the melon fruits interfere with proper tillage. It competes for moisture, and is host to plant bugs that attack citrus fruits.

Morning glory type vines of the genus *Ipomoea* are often troublesome. These are known by common names such as cypress vine, wild potato, and moonvine.

Brazilian nightshade (*Solanum seaforthianum* Andr.), Virginia creeper (*Parthenocissus quinquefolium* (L.) Planck), bamboo vine (*Smilax laurifolia* L.), *Bignonia* vines and several other species including poison ivy often occur as vine pests.

Other Grove Weeds.—Aside from the grasses and vines, a few other weeds were listed several times in the survey data as being important. These are:

Polkberry (*Phytolacca rigida* Small), which frequently is seen emerging and fruiting through the canopy of citrus trees 15 to 20 feet tall (Figure 4).

Elder (*Sambucus* sp.), the common elderberry.

Jerusalemoak, of the Goosefoot genus (*Chenopodium*).

Cocklebur (*Xanthium* sp.).

Ditch Weeds.—This group is fully as important as any of those previously listed, not only with respect to citrus production but to nearly every other kind of agricultural land use in the level areas of Florida. In groves in the coastal areas, water control is so important that the canals and ditches must be considered as an integral part of the citrus lands. Expense of maintaining these ditches to assure free flow is high, ranging from $20 to $200 per mile. Draglines and much hand work is required, although chemical control with 2,4-D and 2,4,5-T brush killers and with monuron shows promise in some cases. When chemicals are used, care must be taken not to kill all vegetation or erosion will occur.

Ditch weeds are of various kinds, including cattails, saggittaria, primrose willow, guava, myrtle and hyacinths as well as the previously men-

TABLE 1.—Number of Dollars Spent Annually for Weed Control Operations.

	Range	Mode	Mean
Citrus nurseries, per acre	15-135	25	50
Young groves, per acre	4-75	10	15
Old groves, per acre	3-50	6	10
Ditches, per mile	20-200	100	90

tioned weeds such as paragrass, maidencane, elder and various vines that can spread out from ditches into the groves.

While it is not the intention in this paper to delve into specific weed control procedures, some basic points are worthy of discussion. As in other farming operations, the recognition of future hazards in operating a citrus grove can avoid a great deal of trouble and expense later. The survey reported herein disclosed that growers are presently expending the approximate amounts shown in Table 1 for weed control although in many cases this control is far from adequate.

Young Groves.—Planting a grove involves a considerable investment over many years. The first five years is all expense, often amounting to $15 per tree before any return is received. Later the tree can acquire a value of more than $40 at today's market. In acquiring land for new citrus plantings, former pasturelands should be avoided unless the grower is prepared to furnish sufficient money and careful supervision to see that pest grasses are eradicated before the first tree is planted. A number of growers have learned by experience that partial control of pangola grass and torpedo grass is not sufficient. They have had to cultivate, hand hoe and irrigate excessively and they still have the grass. The concentration of roots and rhizomes stunt and even kill young trees.

In a young grove, plowing plus the use of herbicidal chemicals may eliminate the weed from the middles but unless the roots are eradicated from the tree rows as well, clearing the middles is only a temporary victory. Once the weeds become established under the trees their roots become so intermingled with the citrus roots that adequate hoeing or tilling cannot be practiced without harming the tree. Likewise the possibility of using chemical herbicides under the trees depends on materials of extreme selectivity being available. Thus, since a new citrus tree will remain in the same spot for 50 years or more, the eradication of noxious weeds from the planting site will justify considerable initial expense. Where the site is adjacent to established stands of potential grove weeds, whether they are in pastures, ditches or lakefronts, provision should be made for a barrier strip.

Mature Groves.—In mature groves the weed situation is somewhat different. By that time the tree roots have grown out to the adjacent trees which makes deep plowing and the use of chemicals more hazardous in the middles. On the other hand, shading may have reduced some weeds and in general older trees are more tolerant of herbicides. Weed problems in old groves usually have arisen from a combination of two things: a location adjacent to sources of pest weeds and a period of neglect sometime in the history of the grove.

New methods of combatting weeds are being developed each year, some of which will almost certainly help the citrus grower. Numerous chemical herbicides have been developed during the past 15 years but only a few of these are sufficiently selective for use with tree crops. Both 2,4-D and 2,4,5-T are too injurious to citrus at the concentrations necessary, to be of much value and they do not kill grasses. Dalapon is effective against many of the grasses but cannot always be used with safety close to citrus trees. The substituted urea compounds such as monuron and diuron show much promise, although the tendency of these materials

to have a semi-sterilizing effect on the soil warrants a lengthy experimental period for evaluation.

New types of tillage machines known as rotovators and rototillers, as well as several types of mechanical hoes and choppers, are being used and improved each year. When further experience is gained with these chemical and mechanical aids, the citrus grower can anticipate better ways to control his weed problems.

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Herbicides for Crop and Industrial Uses

Wm. D. Hogan *

The past 15 years have witnessed tremendous developments in the field of chemical weed control, and these developments have been almost entirely in the field of organic chemistry.

Until 1945 weed control measures on the farm and in the industrial field consisted almost entirely of mechanical and cultural techniques. Weeds occurred so commonly in the fields and industrial areas that they were accepted as inevitable intruders.

Losses from weeds are generally much greater than most of us appreciate. Last year the average farmer in the United States lost at least $500 because of weeds; more recent estimates indicate that on a nationwide basis weeds cost us about $5 billion per year. This is many times the cost of all animal diseases and more than that due to combined destruction of insects and plant diseases in our crops.

Admirable advances have been made in cutting into these losses through chemical weed control. Cotton is a good example. Cultivating and hoeing can account for 75-85% of the pre-harvest man hours, at a hoeing cost ranging from $5 to $40 per acre. The use of chemicals for weed control can eliminate at least one hoeing, and in some cases as many as four hoeings, at a chemical cost as low as $2.50 per acre.

With the increasing labor costs and the scarcity of adequate farm labor, the farmer's need for weed control chemicals is intensified and we can predict further significant progress in this field.

The chemicals used in weed control may be divided into three groups. These are (1) the selective herbicides, (2) the non-selective herbicides, and(3) the soil sterilants. Selective weed control came into being when the striking effect on plants of 2,4-D was announced in 1944. The various compounds of 2,4-D are inexpensive, selective, easy to apply, and adapted to a wide range of problems. Here in Florida we are familiar with these products for the control of broadleaved weeds in corn, in sugar cane, and for water hyacinth control in our lakes and rivers. Other selective weed killers include the dinitros, phenyl carbamates, and 2,4-dichlorophenoxyethyl sulfate.

The non-selective materials are those that kill the top growth of plants regardless of species. They may or may not be translocated and are applied to the foliage of the weeds and brush. Some of these non-selective herbicides are the aromatic oils, sodium arsenite, sodium chlorate, and ammonium sulfamate. Du Pont offers this last compound under the trade name of "Ammate" weed and brush killer. It is ideal for killing many of the hard-to-kill weeds and brush. This product is absorbed by the leaves and translocated to the roots to kill both the roots and the foliage.

These non-selective herbicides have contributed markedly to improved and lower cost industrial weed and brush control. Utilities, for example, have extensive rights-of-way which must be maintained clear of large

* E. I. DuPont de Nemours & Company, Inc., Atlanta, Georgia.

growing brush. Mechanical clearance and hand cutting were standard procedures of maintenance in the past. However, aggressive action by the utilities in overcoming the shortage of manpower has resulted in wide usage of chemical brush control programs with greater efficiency at lower costs. For example, on a telephone line in Oklahoma the cost of hand cutting mixed brush five to 15 feet high averaged $650 per mile; chemical spraying cost $130 per mile for the same right-of-way.

The soil sterilants may be divided into those that are temporary, leaving no injurious residue, and those that are semi-permanent, preventing any plant growth while their residue remains in the soil. Some of these temporary compounds are chloropicrin, methyl bromide, sodium TCA, and Vapam. Others that are semi-permanent soil sterilants are sodium arsenite, sodium chlorate, the boron compounds, and the substituted urea compounds.

We offer these last compounds under the trade names of "Karmex" herbicides for farm use and "Telvar" weed killers for industrial weed control. They are highly effective herbicides that control a wide range of annual and perennial grasses and herbaceous weeds at comparatively low dosages. They offer weed control with these outstanding safety advantages: they are of a low order of toxicity to warm-blooded animals; they are noncorrosive, nonvolatile, and nonflammable.

Here in Florida the "Karmex" herbicides are recommended for weed and grass control in gladiolus, sugar cane, Asparagus fern, potatoes, irrigation ditches, and for general farm weed control. Let me cite one interesting example of the substantial savings made possible by chemical weed control. For years the average Asparagus fern grower has spent about $300 per acre per year for hand weeding; last year the average fern grower using "Karmex" herbicide controlled 91 per cent of the weeds growing in his shed for $45 per acre.

"Telvar" weed killers are especially recommended for use in industrial areas such as railroad installations, electric substations, gasoline tank farms, and drainage ditches. It has been used for total vegetation control in industrial areas since 1950. Here in Florida rates as low as 50 pounds of the 80 per cent wettable powder per acre provide practical control of most vegetation under our climatic conditions for about twelve months.

Where do we go from here in weed killer research? First of all, we must be practical, we must produce a product that will fill a definite need. Yet while we must be practical, we still must not be afraid to dream. There are at least 2 million acres of scrub oak and palmetto land in Florida that could be put into production if we could find a good, inexpensive method of chemical weed control—think what this would do for our future citrus, vegetable, livestock, and pulpwood supply! We need a good aquatic killer to free our waterways from parrot feather and kinky wool, to mention just two of our many water weed problems.

We are rapidly reaching the limits of our land—our new frontiers are in science—in making the most of what we have in terms of human values and natural resources. The future holds for us many new and interesting developments in the field of weed control, so in closing let me voice the hope that we will continue to achieve better things for better living . . . through chemistry.

Progress Report on Retting Kenaf and Jute Ribbons

T. E. Summers, J. W. Randolph, M. H. Byrom and R. V. Allison *

The degree of success of an endeavor to develop a commodity to be used as an alternate for an established product or source is measured by the feasibility and facility with which the substitute can be produced and manufactured, as well as by the degree to which it may otherwise satisfy requirements met by the product replaced. The raw jute fiber and burlap used in the United States represent the best quality fiber and burlap obtainable from India and Pakistan(7). Actually, all the fiber produced by these countries, using long established water-retting and hand-stripping methods, is not of the high uniform quality products imported into this country. However, it is only to this best quality jute fiber and burlap from these countries (which for years have supplied most of this country's jute fiber and burlap), that domestically produced fiber is compared(7) and would replace should the occasion arise.

An unwillingness of laborers to work with tank retted kenaf fiber in 1955 served to focus attention on some of the problems associated with water-retting of soft fibers. These problems are peculiar to large scale retting operations, are not encountered and consequently probably will not be entirely solved, in small laboratory experiments. This view is held by certain other workers in this field(1,9).

The most important problem which would confront a large scale soft fiber production effort in this country is that of extracting the fiber, whether it be jute or kenaf. Some specific problems encountered in water-retting kenaf in tanks, plus certain other inherent disadvantages of tank-retting suggested a need for an improved or different technique for retting kenaf and jute in quantity under our labor economy. Therefore, in addition to retting in concrete tanks and surface water canals, two methods of aerobically retting kenaf and jute ribbons were investigated. One of these aerobic schemes, commonly known as either stack, spray, drip or sprinkler-retting, has been described in the literature(4,9,10). The other, for which the designation "moist chamber retting" is proposed, is currently being developed at the Everglades Experiment Station, Belle Glade, Florida.[1]

Complicated chemical and elaborate patented biological retting systems which require expensive equipment and technical supporting operations have received little consideration, as it was felt that a relatively simple, reliable method could be found or developed by which a fiber will be produced satisfactory for use by domestic spinning equipment and acceptable as an alternate for imported fiber.

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[1] Annual report for 1955 to the Cotton and Other Fiber Crops Section, Agri. Res. Service, by Thomas E. Summers, copies deposited at Beltsville, Md. and office of Director of Fla. Agri. Expt. Stations, Gainesville, Fla.

This is a progress report concerned with an investigation to evaluate the present and potential possibilities of these four schemes of biologically retting jute and kenaf fiber in the Everglades area of Florida.

SOURCE OF MATERIAL

The material used in these studies in all cases was machine produced ribbons, either by an experimental machine being developed by the U. S. Dept. of Agriculture Engineering Research Branch or a machine produced by Baproma, Inc. and known as the "Baproma."

In 1955, kenaf varieties Cuba 108, Cubano, and a composite of seed developed by the U. S. Dept. of Agriculture Field Crops Research Branch were used, and in 1956, varieties BG-52-41 and Cubano were used. These varieties all appear to be closely related, have been developed from a common seed source, and no differences in retting qualities were observed.

METHODS OF RETTING AND RESULTS

In 1955 the retting work was predominantly with tanks and stack-retting with a few preliminary "moist chamber" rets carried out in a regular pathology moist chamber. In 1956, canal-retting was added and more moist chamber trials were made.

Tank Retting

In these experiments, a 50 x 6 x 6 foot tank divided into a series of 6 x 6 x 6 foot sections was used. Surface canal water was used with the exception of the first series of rets in which rain water was used. The canal water proved as suitable as the rain water. In 1955, rets were completed without changing the water in the first experiments. In later experiments, one-half of the solution was drained off the third day. Gondolfo (6) had found that changing the retting solution in the first 24 hours improved the quality and color of retted flax fiber and in 1956, the entire solution was drained and replaced with fresh water on the second and sixth days if the ret was not completed by the sixth day.

Fiber of good quality was produced except in cases of unexplainable "poor rets" in which case the ribbons failed to ret properly, leading to poor cleaning of the fiber with the fibers of the "fingers" (the fibers of one stalk or ribbon) adhering and giving a harsh and brittle feeling fiber.

An evaluation of a small sample of good tank retted fiber by one of the larger domestic jute spinning mills was as follows: "Here you have a very excellent fibre, good strength, well cleaned and good color. It appears to have good spinning quality and should give a carding loss no higher than any good Indian Dacca Tossa 4 grade of jute." The tank retted fiber tested a tensile strength of 38,800 pounds per sq. in. in 1955 and 32,700 in 1956 (Table 2).

The spinning report on the bulk tank retted fiber (1955) was as follows: "The fibre processed without any particular difficulty. The waste loss was 2½% higher than jute. The yarn samples give the following results—1,125 yards per pound. 18 lb. tensile. The sample in effect is 10% light. The tensile would be about 19 lb. if the yardage was correct." The yarn compares favorably with commercial jute yarn and is superior to stack retted yarn (Table 3).

Distadvantages of Tank-Retting:

Some of the specific problems encountered in these experiments were:

(a) Vermin and unsavory appearing condition developed. Large populations of mosquitoes and rat-tailed maggots (*Eristalis tenax*) developed. This condition, in combination with the offensive odor that developed, caused the labor problem mentioned above.

(b) Time required for rets to complete varied with temperature, age and disease condition of ribbons, and location of ribbons with reference to surface of tank. The need for a more shallow tank was obvious.

(c) Some unexplainable poor rets were obtained. Some disadvantages inherent to tank-retting are that construction costs of tanks and associated pumps are high, and a large amount of water is necessary. To secure a uniform controlled ret, temperature controls and a bacterial retting inoculum are necessary. The producing of a bacterial culture in a quantity sufficient to influence a large ret would be particularly expensive, requiring technical personnel and expensive equipment.

Canal-Retting

In this operation, the ribbons were simply placed in bundles and weighted down in one of the surface drainage canals on the Experiment Station. The same difference in retting rate near the surface and at deeper depths was observed as in tank-retting. When ribbons were loosely submerged to a depth not greater than one foot, a good quick ret was obtained. When the ribbons were closely packed and weighted to the bottom of the canal, a longer period of time to ret was required.

The strength of the canal retted fiber was good, 36,200 pounds per sq. in. (Table 2). No mill tests have been made on this fiber.

Moist Chamber-Retting

That fungi may act as retting agents was suggested by Behrens(2) and Ruschmann(8) some years ago. Fuller and Norman(5) listed several common fungi as occurring on field-retting flax. Isolations were made from kenaf ribbons observed to be in the process of retting which were in contact with the ground. Kenaf ribbons hung in a moist chamber and sprayed with several of these isolates and kept moist by a common throat atomizer connected to compressed air and a water source retted more rapidly than the uninoculated checks during cool weather. During warmer weather, no difference could be detected between inoculated and uninoculated ribbons. At temperatures of 75° F. and above, ribbons retted in 2 to 3 days. During cooler temperatures, 50 - 75° F., uninoculated ribbons took up to 6 days to ret while the inoculated ribbons took from 38 to 96 hours. One isolate destroyed the fiber (Table 1).

It should be mentioned here that the soil type upon which the ribbons are grown markedly affects the ease with which retting takes place by this method. Ribbons grown on coastal sand ret very poorly unless inoculated. However, since this is a comparison of techniques rather than cultural practices, this problem must be dealt with at a later time.

Fiber quality produced by this method in 1955 was better than stack retted fiber but weaker than tank retted fiber. In 1956, a more uniform

TABLE 1.—Hours Required for Moist Chamber Retting Kenaf at 60 - 75°F. Temperatures Using 5 Fungus Isolates Collected at Belle Glade, Florida.

Isolate Number	Hours Required for Retting
Check	132
1	60
2	96
3	48
4	46
5	Fiber Destroyed—No Ret
1 + 3	38

TABLE 2.—Strength of Kenaf Fiber; Tank, Canal, Moist Chamber, and Stack Retted in 1955 and 1956. Determinations Made at Belle Glade, Florida, Pounds per Square Inch.

Method	1955	1956	Average
Tank	38,500	32,700	35,600
Canal	....	36,200	....
Moist Chamber	28,800	37,000	32,900
Stack	18,000	29,400	23,700

TABLE 3.—Comparison of 14 Pound Yarns Made from Tank and Stack Retted Kenaf Fiber with a Cuban Produced Kenaf Yarn and Two Commercial Jute Yarns.

Description	Pound Sq. Inch ½ Inch Tensile	½ Inch Breaking Strength
Kenaf—tank retted	38,500	19.0
Kenaf—stack retted	16,500	14.4
Kenaf—stack retted	16,400	11.8
Kenaf—(Cuban)	25,400	16.3
Jute—commercial	28,800	25.3
Jute—commercial	35,700	20.6

TABLE 4.—Length of Time to Ret Kenaf Fiber by Tank, Canal, Moist Chamber, and Stack-Retting Methods in 1956. No Temperature Control.

Method	Time Range	Average Time
Tank	5 - 18 days	8 days
Canal	13 - 21 days	17 days
Moist Chamber	2 - 6 days	2.5 days
Stack	3 - 6 days	5 days

product was obtained and the quality (at least for tensile strength) equaled tank and canal retted fiber. The strength for 1955 and 1956 respectively was 28,800 pounds per sq. in. and 37,000 pounds per sq. in. (Table 2).

The advantages to such a scheme are:

(a) Rapid rate of retting.
(b) Little expensive equipment necessary.
(c) Small volume of water necessary.
(d) No objectionable odor involved.
(e) Small amount of inoculum necessary for controlled ret.
(f) Lends itself well to an in-line mechanical operation.

The disadvantages at present:

(a) No mill tests have been run. (This will be accomplished in the near future.)

(b) All extraneous matter must be removed in the washing or cleaning operation. Much of this matter may be dissolved and carried away in water retting.

(c) More experimental work necessary to determine costs and best operating procedure.

Stack-Retting

Watkins and Allwood(10) reported retting stems, crushed stems, and ribbons in stacks, both without water and with water sprinkled over the stacks. They reported a minimum of 18 days for kenaf ribbons to ret, but stated that the quality of fiber was apparently equal to water retted fiber. Burkett, *et al.*(4), however, did not find stack retted fiber to be of good quality. Thieme(9) in 1954 described stack-retting of jute and kenaf ribbons with good success, though he admitted the product was no more uniform than water retted fiber. He reported no mill tests.

Stack-retting here closely followed the procedure described by Thieme and consisted of stacking the ribbons on a wooden framework about 6 inches off the ground (to allow air circulation). The stacks were left several hours until a temperature of 30° to 40° C. was reached. The following morning, or if the stacks had been made in the a.m., then in the afternoon of the same day, the stacks, which were arranged in a circular pattern, were sprinkled, using an ordinary commercial rotating arm lawn sprinkler.

Muck grown ribbons were completely retted in 3 to 5 days. In this method, as with the "moist chamber" method described above, sand grown ribbons failed to ret as readily as ribbons grown on organic soil. Bose reports using a fungus to obtain a rapid stack ret in India(3). Since inoculating ribbons grown on the sand improved the rate of retting in the moist chamber method, it may well be that certain soils do not naturally furnish the necessary retting organisms.

A considerable amount of fiber was produced by the stack-retting method in 1955. An evaluation of the fiber by jute spinning personnel was as follows: "Stack retted kenaf—the material as received, would not be suitable for spinning. It might be possible to develop batching emulsions and procedures to further the retting action. . . . Under any

circumstances, except war or other emergency conditions, the economic return on this product would be penalized."

The spinning mill report reads: "We were able to make up 130 lbs. of the material in balls, and unfortunately because of the bad condition of the fiber, have also 200 lbs. of sliver waste which we could not process into yarn."

While the tensile strength of the 1956-produced fiber was better than in 1955, the poor quality fiber, both as to strength (Table 2) and milling quality in 1955, was not encouraging. The yarn compared unfavorably with both jute and water retted kenaf fiber yarn (Table 3).

In correspondence with one of the authors,[2] Mr. R. K. Kirby of the Colonial Products Laboratory, London, states: "About two years ago, we examined, in cooperation with the British Jute Trade Research Association, some samples of *Hibiscus* fibre which had been sprinkler retted by the method described by Dr. Thieme. At the same time, samples were also sent us of *Hibiscus* retted by ordinary tank methods. The spinner's report on the samples showed that the tank retted material was superior as regards fineness to the fibre produced by the sprinkler method. It did appear, however, that the sprinkler retted fibre was insufficiently retted and it is possible that a better-quality fibre could be obtained with more experience. As far as we are aware, however, no further trials with the sprinkler method have been carried out in East Africa."

DISCUSSION AND RESULTS

With spinning mill tests completed on fiber produced by only two of the retting methods tried, a final evaluation of the most feasible method to use must await further tests. However, from usage, preliminary tests, and general feel and appearance of the fiber, it can be assumed that canal retted fiber is equal to tank retted fiber. Tank retted fiber yarn compared favorably with commercial jute yarn. Tank retted jute grown at Belle Glade, Florida, had a tensile strength of 34,400 lbs./sq. in. This makes kenaf fiber (Table 2) compare favorably with a comparable jute sample.

Some average times for retting to take place using the four methods are given in Table 4. If the fiber produced by the moist chamber method is acceptable to the spinners, the rapid rate of retting, along with less variation in time should prove of considerable value in a production operation.

Unless the quality of a fiber produced by the stack-retting method can be materially improved (and that should be possible), it would be used only in an extreme emergency. Certainly on the basis of only two seasons' work, the method should not be abandoned experimentally. However, on the basis of the information derived from these investigations, the method would not be recommended except with reservations for commercial use.

SUMMARY

Tank retted kenaf fiber was superior to stack retted fiber in all respects. Canal retted fiber equalled tank retted fiber in strength. Moist

[2] Letter dated Nov. 14, 1956 from Mr. R. H. Kirby, Colonial Products Laboratory, to Dr. R. V. Allison, Everglades Experiment Station, Belle Glade, Fla.

chamber retted fiber compared favorably with tank and canal retted fiber in strength and has not been compared in spinning tests. An average of 8 days was required for tank-retting of kenaf ribbons, 17 days for canal-retting, 5 days for stack-retting, and 2.5 days for moist chamber retting.

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Harvesting Grass Silage in the Everglades

DALTON S. HARRISON and ROBERT J. ALLEN, JR.*

In recent years considerable work has been done in an effort to develop an economical program for the preparation of grass silage as winter feed for cattle in the Everglades area of south Florida. This work has led to the development of certain modifications and innovations in the machinery and equipment used for harvesting grass and applying preservatives. This report covers the progress made along these lines to date.

SILO TYPES:

With the exception of two upright concrete structures built at the barn about 1938, silos have been "above the ground" or bunker type with open ends, and have been located in separate pastures. They have been 48 feet long, 12 to 14 feet wide, and 6 feet high, constructed of braced posts with either airplane landing mat or woven wire fence sides. The bottoms have been covered with marl rock. They are filled by pulling the wagons through the open ends and unloading the chopped grass directly into the bunker.

The large amount of spoilage in open wire silos has caused serious concern and investigations are under way on silo structures which will eliminate some of this spoilage. A silo 96 feet long, 15 feet wide, and 6 feet high with sloping sides was constructed of creosote treated timbers and matched boards this past summer. It was filled but has not yet been opened.

EQUIPMENT:

A direct cut forage harvester with auxiliary engine has been used exclusively, and this type of equipment is recommended for the heavy stands of grass common in this area. A two-plow tractor has been sufficient for pulling the harvester and wagon in the field. However, it was necessary to use a crawler tractor to give sufficient traction to pull fully loaded wagons up onto the grass in partly filled silos.

The wagons used were of the self-unloading slat conveyor type operated from the tractor power take-off. They proved very satisfactory in that they unloaded with a relatively even distribution through the bunker.

Due to the great amount of flotation desirable on muck soils airplane tires (32 x 8) were used on the harvester and wagons. The wheel on the engine side of the harvester was dualed. The rear wheels of the wagons were also dualed so as to provide greater bearing surface while being pulled over chopped grass in the bunkers.

Tapered wire covered tops were added to the wagons so that chopped grass leaving the discharge chute would be trapped in the wagons in case of strong winds while harvesting (Fig. 1).

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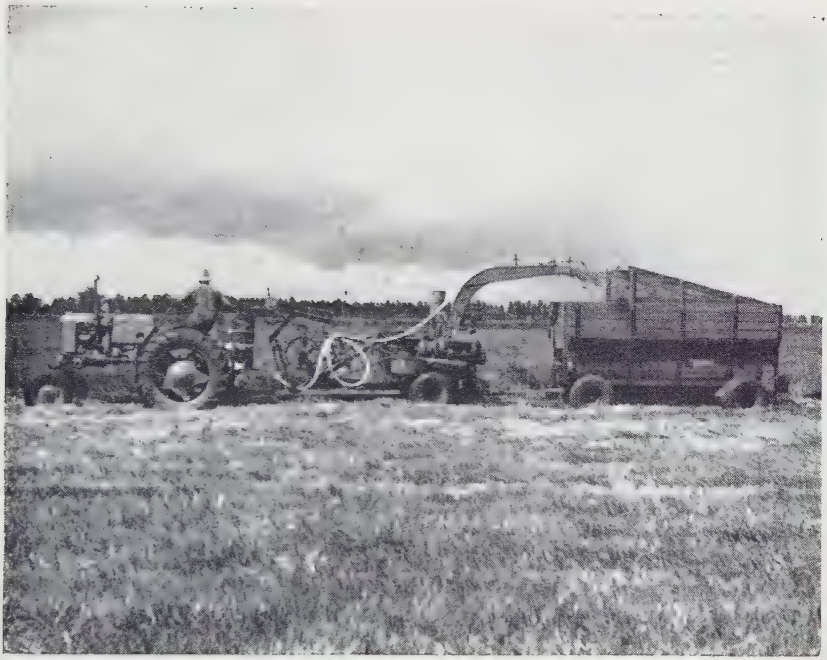

Figure 1.—Field harvesting equipment in operation at Everglades Experiment Station, Belle Glade. (Note preservative application equipment installed on tractor and harvester, and tapered wire cover on wagon box.)

ADDING MOLASSES:

During the first season molasses was diluted (3 parts molasses to 1 part water), fed through a rotary pump and sprayed by hand through a 1 inch hose. This operation was performed after the grass had been unloaded and spread. It required an additional man for applying the molasses and was quite apt to hold up the unloading of the following wagon.

During the last two seasons undiluted molasses has been added mechanically during the harvesting operation. A 55 gallon drum was mounted on the rear of the tractor (Fig. 2) and a 1½ inch line fed undiluted molasses to a pump mounted on a frame attached to the rear-axle of the tractor (Fig. 3). This pump is a 1½ inch Viking H 124-S bronze fitted internal gear pump equipped with a relief valve and is chain driven from a sprocket on the tractor PTO shaft. A 1 inch neoprene hose was run from the pump to the end of the harvester discharge chute (Fig. 1). A bracket on the end of the discharge chute held a ¼ inch pipe T into which were drilled two ⅛ inch holes through which the molasses was discharged into the stream of chopped grass as it was blown into the wagon. Although the molasses could not be sprayed, it was reasonably well distributed and the method worked satisfactorily.

As the temperature increased during the day and the molasses became less viscous, the first T was replaced by another with three 3/32 inch

Figure 2.—Molasses tank attached to rear frame of tractor.

Figure 3.—Molasses pump attached to rear axle and frame of tractor.

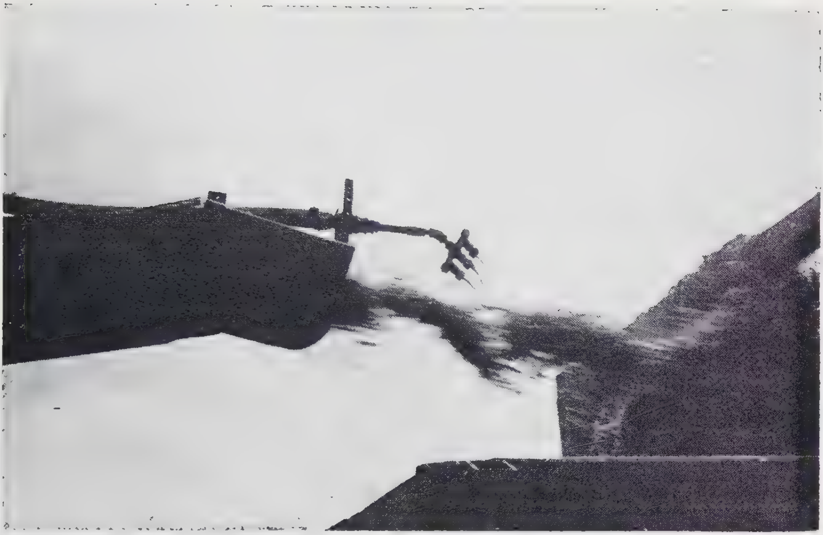

Figure 4.—Molasses being applied through nozzles to the chopped grass as it leaves the discharge chute.

Figure 5.—Bisulfite hopper attachment directly over feed roll table.

holes. In this way a relatively uniform rate of approximately 100 lbs. (8½ gals.) of molasses per ton of grass was maintained.

Toward the end of this season the above T's were replaced by a set of three Bete Fog nozzles (Fig. 4), which have interchangeable discs with different size orifices. These appeared to be more satisfactory than the previous method during the few days that they were used.

An inexpensive, double gear, cast iron 1½ inch pump, powered through reduction gears by a 4½ h.p. gasoline engine, transferred molasses from a 250 gallon trailer tank to the drum on the tractor.

Adding Sodium Metabisulfite:

During the first season bisulfite was spread by hand at 8 pounds per ton after the grass had been leveled in the bunker and then was raked in lightly to get better distribution. In order to seal the gas in the stack, this operation was performed just before the next wagon was unloaded.

After the first year, a star-wheel type fertilizer hopper for adding the bisulfite was mounted on brackets directly over the feed roll of the harvester (Fig. 5). The drive shaft of this unit was extended over the end of the drive shaft housing of the harvester feed roll. The collar of the harvester feed roll drive shaft was removed and a V-belt pulley installed to drive the shaft of the hopper. A counter shaft was used to get the desired reduction (10:1) in order to drive the hopper shaft at 7 rpm and deliver 8-10 pounds of bisulfiate per ton of chopped grass. A thorough mixture was obtained by the knife and blower mechanism.

Silo Covers:

In the summer of 1955, four of the bunker type silos were fitted with Ultron Flexible Vinyl Plastic covers at a cost of about $50.00 per silo. These covers were attacked and damaged, presumably by insects. Their use is still being investigated.

TABLE 1.—Cost of Equipment Used.

1—Forage Harvester	$2,268.50
2—10,000 lb. capacity wagon chasis at $175.00	350.00
2—7,000 lb. capacity wagon boxes at $410.76	821.52
Extend rims on chasis, and lumber for boxes	118.00
Dual 1-wheel of forage harvester	43.32
15—Airplane tires for wagons and harvester at $2.00 (war surplus)	30.00
Hardware cloth for top of wagons	10.56
1—Fertilizer hopper for bisulfite distributor	29.00
1—Viking Pump, Model H-1245, bronze fitted, with relief valve, 1½ inch 10 gpm, 200 psi	110.00
1—Gould Rotary Gear Pump, cast iron 1½ inch	21.00
1—250 gallon tank, mounted on trailer	200.00
	$4,001.90
Silo Covers (for 4 silos 14 ft. x 48 ft. x 6 ft.)	
1—Roll 175 yds. x 72 inches wide, .008 inch thick, clear Ultron Flexible Vinyl Plastic	$ 175.00
144—Yards Scotch Plastic Electrical Tape No. 471, 2 inches wide, for splicing covers	24.00
Cost of cover per silo	49.75

TABLE 2.—Operating Costs for Harvesting Grass Silage at the Everglades Experiment Station (1955-56).*

Grass Variety in Each Silo	Fuels and Lub.		Preservative Mol./Bisulfite		Total Labor—3 Men at: $0.85/hr.	Total Labor—3 Men at: $1.00/hr.	No. Tons Harvested		Rate of Harvesting (Tons/Hr.)		Total Cost per Ton	
	1955	1956	1955	1956	1955	1956	1955	1956	1955	1956	1955	1956
Para	$22.25	....	$ 71.95	....	$68.85	....	90	......	3.3	....	$1.81	......
St. Augustine	18.45	$16.20	69.30	$105.16	49.73	$ 60.00	84	100	4.3	5.0	1.64	$1.81
St. Augustine	....	37.70	....	134.01	....	132.00	......	198		4.5	......	1.53
St. Augustine	....	16.75	....	75.70	....	60.00	......	101	....	5.0	......	1.51
Pangola	23.05	24.15	115.37	95.01	76 50	99.00	106	102	3.5	3.0	2.04	2.14
Carib	20.75	32.20	140.73	116.26	60.13	99.00	118	126	4.3	3.8	1.87	1.96
Avg. Cost/Ton	$ 0.21	$ 0.20	$ 0.99	$ 0.84	$ 0.64	$ 0.72					$1.84	$1.76
Percent of Total Cost	11%	11%	54%	48%	35%	41%						

* Fuels and lubricants cost: Gasoline at $.25 per gal., Diesel at $.15 per gal., and Oil at $.30 per qt. Sodium metabisulfite at $.10 per pound and Molasses at $.01 per pound.

Costs:

Although the initial capital outlay for equipment required to begin a grass silage program may seem high (Table 1), this cost may be distributed over a period of years and the actual cost per ton will be dependent on the number of tons harvested.

Figures on harvesting costs compiled at the Everglades Experiment Station during the summers of 1955 and 56 on over 1,000 tons show an average cost of only $1.80 per ton. Of this total cost, approximately $1.00 is for preservatives and $0.80 for labor, fuels, and lubricants (Table 2).

Although spoilage in wire sided bunkers has averaged about 30 percent, ranchers can still produce good quality winter feed for approximately $2.60 per ton.

Handling costs in feeding out the silage are difficult to estimate accurately, but have been held quite low by installing self-feeding gates in the bunkers.

For a discussion on other phases of the silage program see "Winter Feed on Everglades Pasture," page 191 of the Soil Science Society of Florida Proceedings, Volume XV 1955.

Preliminary Studies of Mechanical Dewatering As an Aid To Dehydration of Florida Forages

JOHN W. RANDOLPH,* DAN B. VINCENT ** and R. V. ALLISON *

The harvesting of hay, with all its natural difficulties, has been such a commonplace experience to most of us who were brought up on farms in the temperate zone that we are inclined to feel hay making is hay making the world over and let it go at that. In other words "Make hay while the sun shines!"

Difficulties due to dew, rain and cloudy days, even in the temperate zone, have gradually turned our thinking towards the artificial dehydration of various types and kinds of forage and feed crops. This largely has had reference, however, to what has come to be regarded as "normal" moisture conditions in materials of this nature that are commonly grown in this general area.

When one moves towards the tropics, even as far as Florida, quite another set of conditions are found to prevail. These differ particularly in the much higher moisture content of forages, especially during the rainy season which, of course, is the period of greatest growth and, therefore, the time of most plentiful plant material. An especially high moisture condition usually occurs during the early morning of most days, sometimes extending up to mid-morning or later. It was these conditions, recognized in Florida for many years, which prompted Dr. Luis Rivera-Brenes of Puerto Rico to say in a recent report [1] on this general subject:

> "Hay-making by allowing the grass to dry on the field is impossible in practice because of the frequency of showers in the rainy season and very low yields from scanty rainfall in the dry season. It is in the rainy season that grasses are in the best condition for hay-making."

INADAPTABILITY OF STANDARD DEHYDRATION PROCEDURES TO FLORIDA CONDITIONS

This high moisture content in the forage crops of Florida, and of the tropics, has consistently thwarted the many attempts at hay making by artificial means whether thru the use of the conventional drum-type dehydrator or by the batch system of forced drying. This condition of high moisture in the forage, and these failures at dehydration, largely explain Florida's staggering feed bill which has been estimated at $12,-000,000 to $15,000,000, annually, which is largely associated with dairy

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[1] Technical and Economic Aspects of Roughage Production in Puerto Rico. Technical paper No. 12, September 1953.

operations. Doubtless this same condition is also responsible, in good part, for the deficiency of milk throughout the tropics since a cow simply cannot consume enough green forage, with such a high moisture content, to make her an efficient producing unit.

The principal purpose of this paper is to point out the need for adaptation to agriculture of an industrial process known as mechanical dewatering. This procedure would remove the readily expressable water from Florida forages and other succulent crop materials by way of preparing them either for efficient and effective dehydration or for direct feeding in the undried condition.

MECHANICAL DEWATERING OF CITRUS PULP

Early in the development of the citrus processing industry (canning, freezing, etc.) the disposal of the thousands of tons of waste pulp and fermentable juices quickly proved a serious problem. The effort finally resolved itself into the liming and setting of the pulp after which it was dewatered by a mechanical press. The crumbly press cake that was so formed was readily dried, producing a valuable cattle feed; and the great volume of juice so expressed was reduced to molasses and returned to the dehyrated meal or otherwise used as a cattle feed. The tremendous tonnages of citrus meal and molasses produced annually in Florida since 1940 are shown in Figure 1.

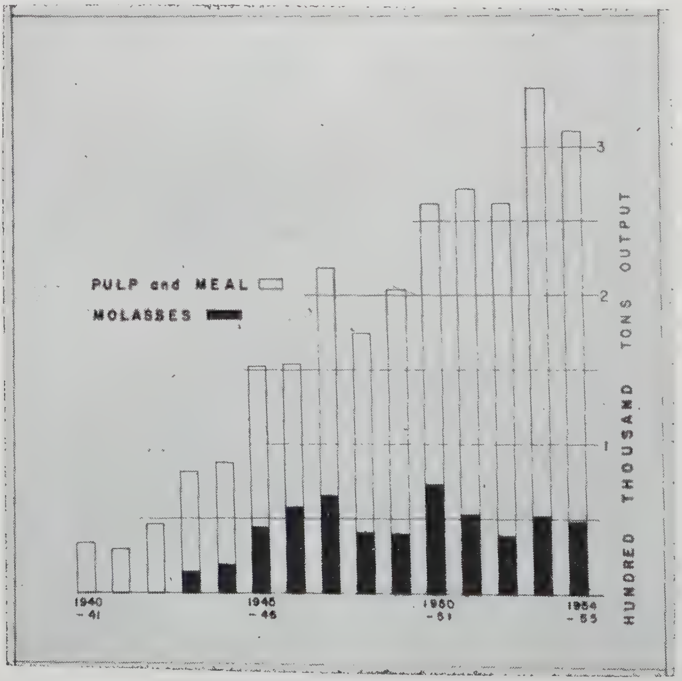

Figure 1.—Annual production of dried citrus pulp and molasses from Florida canning plant wastes since 1940.

THE DEHYDRATION PROCESS

As has been indicated, Florida's cattle industry, especially the dairy industry is badly in need of local sources of dry feeds of good quality in dependable supply and at reasonable cost. These requirements, under existing high costs of farm operations, make certain factors paramount: (1) high yields per acre of uniform, top quality raw material; (2) ability to translate these materials into finished dry feeds through low cost, high capacity, continuous operations that may be carried on in an around-the-clock operation if necessary; and (3) the fullest possible mechanization throughout the process.

The system usually used for expressing moisture relationships in forage materials tends to obscure the magnitude of the water evaporation requirement to make a suitable product. A practical expression of this relationship is the amount of water that must be evaporated to make a ton of finished feed containing 10 percent moisture, a value that is ac-

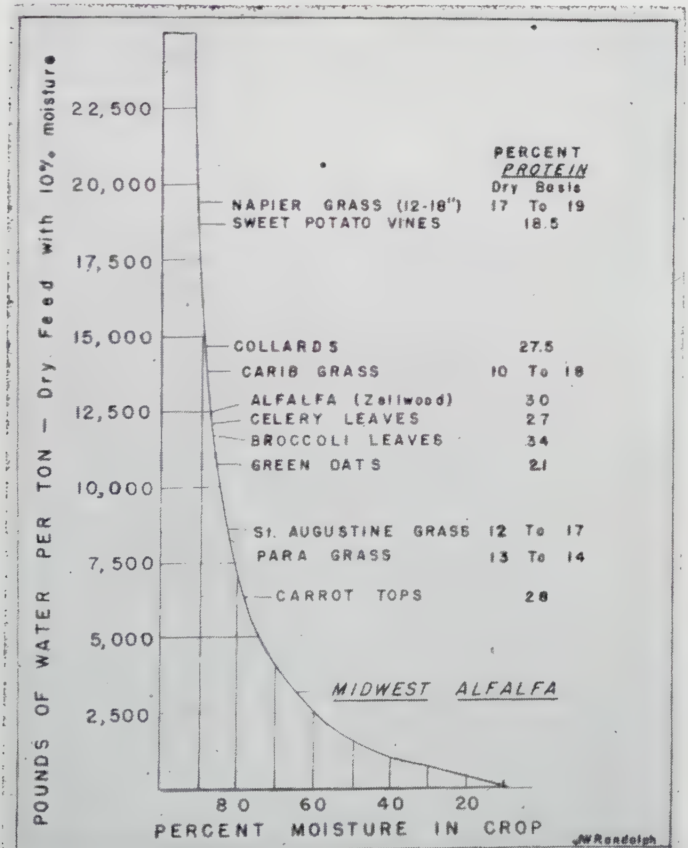

Figure 2.—Pounds of water to be removed from a given forage to produce a ton of feed with a moisture content of 10 percent.

cepted in the commercial market. The Axes of Figure 2 are arranged in such a way as to show a scale of values for each of the two systems of expressing moisture data. The curved line shows the interrelationship of the two systems.

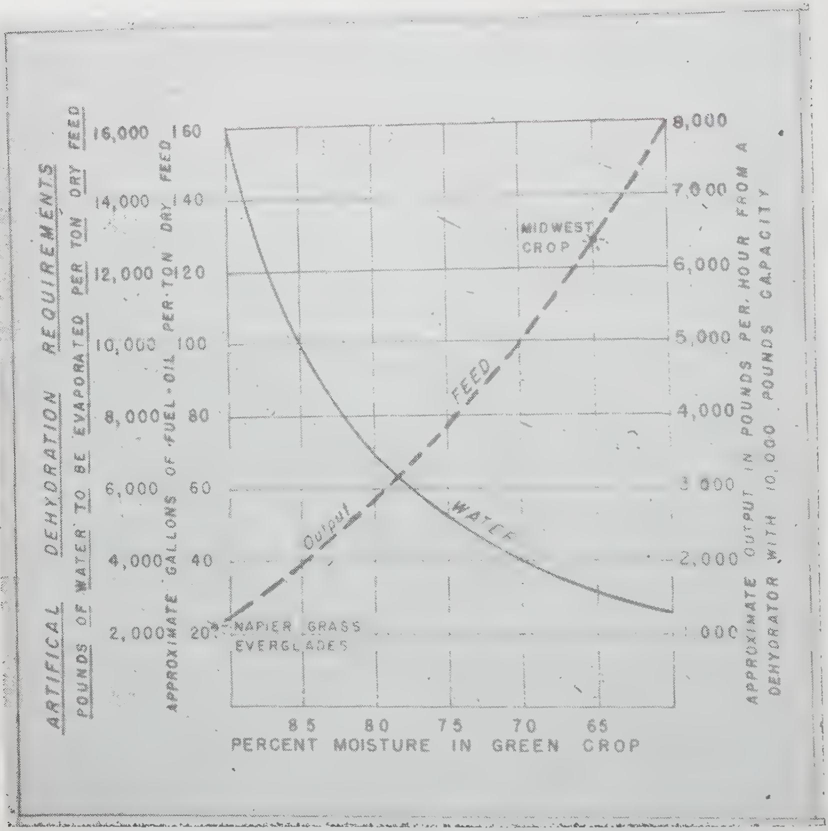

Figure 3.—Approximate output per hour of feed containing 10 percent moisture from a standard dehydrator with a capacity of 10,000 pounds of water per hour working against chopped forage crops of widely varying water content.

Particular attention is called to the changing shape of the moisture curve in that Figure. Thus, forage crops shown in various positions in Figure 2 reveal striking differences as to moisture content when grown in muck soils of the Everglades. The data for "Standard Samples" on this curve has great significance when compared to a general average that has been adopted for what is called "Midwest Alfalfa". Thus, a grazing cow in a midwest alfalfa pasture would consume 2.86 pounds of green material to obtain one pound of dry matter. However, the same animal grazing on young Napier grass in the Everglades would have to eat 11.36 pounds of the succulent material to obtain an equal amount of dry matter. Naturally occurring moisture, such as rains and dews,

also will magnify the differences in green feed consumption under normal grazing conditions especially since our standard breeds of beef and dairy cattle do most of their grazing at night or during the early morning.

Artificial dehydrators are rated on their ability to evaporate a given quantity of water per hour. A unit with a capacity of 10,000 pounds per hour represents a popular size. This capacity has been used in certain calculations to obtain the basic curve pertaining to production shown in Figure 2. There also was used a "rule-of-thumb" value—one gallon of oil will evaporate 100 pounds of water—to give some indication of the cost of the fuel.

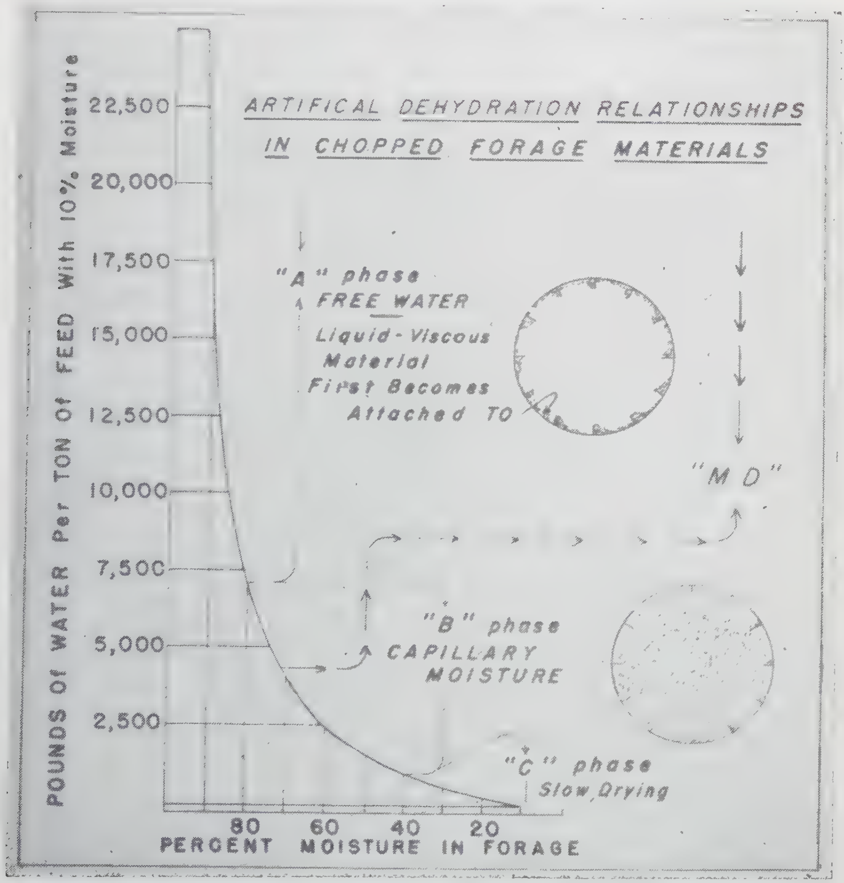

Figure 4.—Phase conditions in artificial dehydration as related to moisture content and the mechanism of drying.

The changes that are shown in the hourly output of finished feed from raw materials having different moisture contents take on very practical significance from the cost standpoint. The starred points in the rate of dehydration curve indicate great differences when the unit was supplied

with "Midwest Alfalfa" compared to Napier grass. Actual difference in the problems of artificial dehydration of forage materials as grown under semi-arid and humid conditions cannot be fully covered at this time.

Certain problems associated with the use of a drum-type dehydrator are indicated in Figure 4. A review of the overall drying process with respect to both troublesome and favorable phases as they are related to the basic curve there reproduced from Figure 1, is a basis for the further discussion of mechanical dewatering. For this purpose the process of drying chopped forage materials with a high moisture content has been divided into three phases or stages, (A) free, (B) capillary, and (C) absorbed.

Problems in the "A" phase were encountered in early attempts to dehydrate citrus cannery waste, a slick, slimy mass of orange and grapefruit refuse containing about 83 percent moisture. This material when fed into the drum-type dehydrator acts similar to wet, chopped forage and defies mechanical or air-current breakup by dropping out as viscous balls directly onto the internal surfaces of the dehydrator. There, as pancake-like masses, attached to the rotating parts, it goes around and around until the processes of broiling, baking and scorching cause it to flake loose and move on and out of the dehydrator.

However, the ideal moisture conditions for a drum-type dehydrator are represented in the "B" phase where the finely divided materials can be air-moved as individual particles, more or less suspended in the air in such a fashion that they set up a restraining curtain to its movement. The heated air, under such conditions, has the opportunity to contact all sides of the raw material and spend its expensive heat in effective evaporation. The modern drum-type of dehydrator is normally equipped with attachments that regulate the heat carried by air and the rate of feeding the raw material. In this way the dehydration conditions are under full automatic control in the "B" phase especially when such materials as press meals are being processed. Such attachments have eliminated a large part of heretofore manual operations. The slowest dehydration phase, noted as "C", does not fall within the scope of this paper.

The artificial dehydration of forage crop materials could be made the subject of a very long discussion. The main differences between such materials and citrus cannery waste are the wide variations in chemical qualities represented in the various crops and in different parts of any given forage plant. Thus, using Para grass as an example, the leaf tip sections of a plant, because of their succulence, are low in fiber and have the highest feed value properties. The coarser sections of the leaves, in various stages of maturity, represent lower feed values. The straw-like stems are high in fiber and have the least food value. Direct dehydration of Para grass, using but one system for the A, B and C phases means, in practice, that much of the leaf tip fractions are burned to ash in order that the stem parts may be dried.

EQUIPMENT AND TESTS

Mechanical Dewatering

Mechanical dewatering is thus to be regarded as a purely physical process primarily designed to totally eliminate the "A" phase moisture

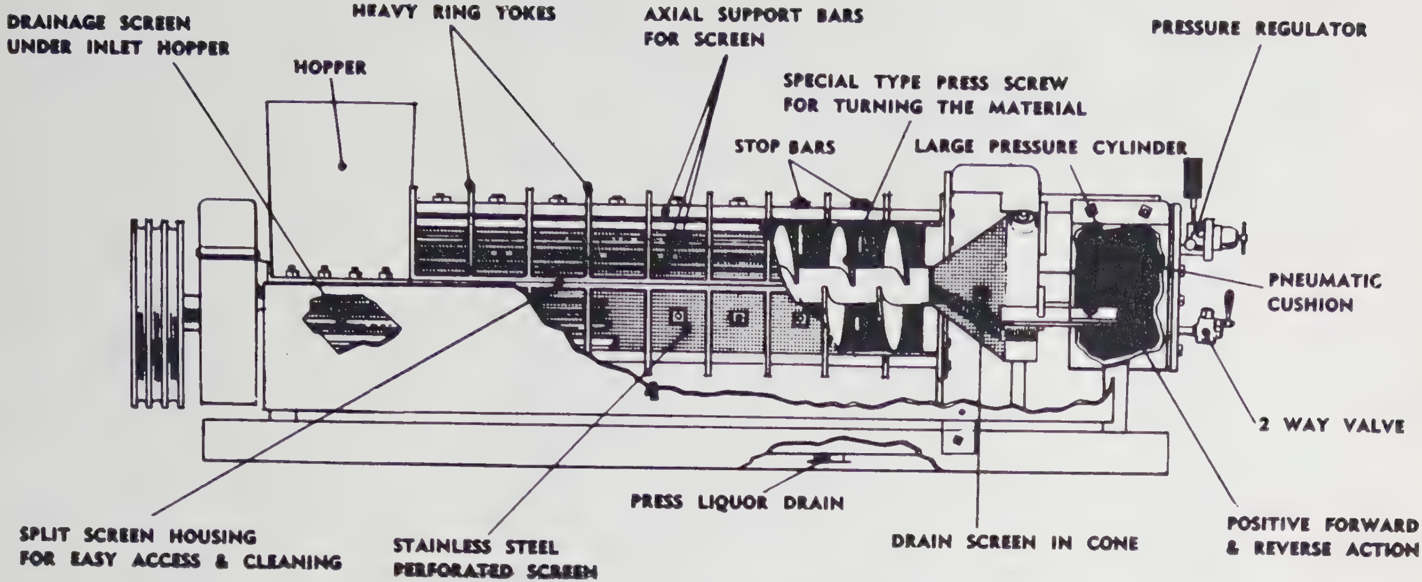

Figure 5.—Sectional view of Vincent press used in dewatering studies. (Patents Pending)

shown in Figure 4. Such a transformation of the forage crop into an easily pulverized press cake which will go directly into the "B" phase of dehydration has many advantages. Of great importance is the physical mangling and crushing of the stem portion of the plant, so that the total mass will dry out rapidly without the destructive burning action on the leaf tip fraction.

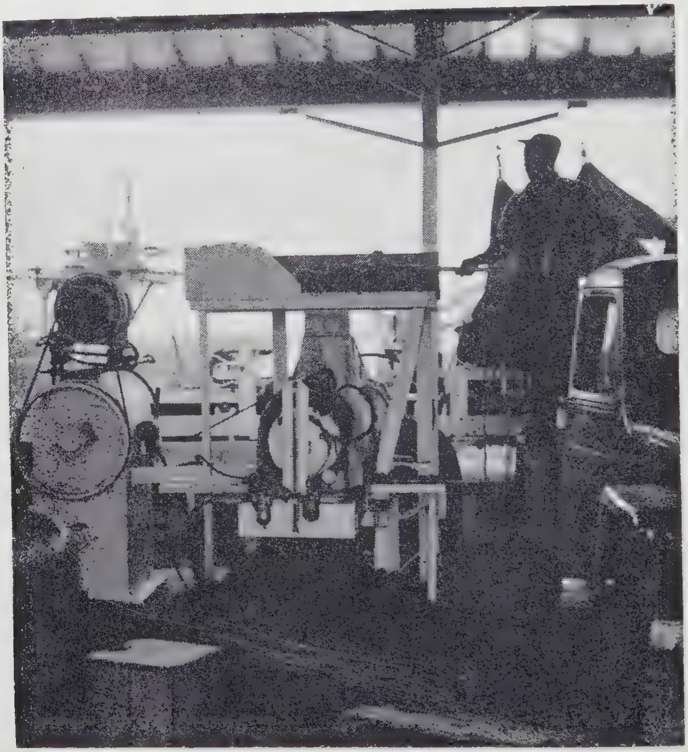

Figure 6.—Discharge end of Vincent press with variable speed drive assembly on left and attendant filling hopper with freshly chopped forage from truck on right.

It is to be recognized that mechanical dewatering, in the absence of salvage work on the press liquors, represents minor losses which shall have to be determined later and decision taken as to whether they are worth salvage thru their conversion into molasses.

The experimental use of the Vincent press disclosed minor problems with respect to its design and construction since it was originally planned for use on tomato pulp. Thus limitations in the range of adjustment of the outlet cone prevented wide experimental differences in the degree of dewatering. In most cases, however, the dewatering process approached a top economic limit in view of other factors not included in this discussion. The power system used for driving the press screw permitted step changes in the revolutions per minute. The dewatering results, with respect to speed of rotation, varied somewhat with different materials.

Mechanical dewatering, as hereafter discussed, is not to be confused with the work of a hay-crusher based upon some very old Cushman patents. Available hay-crushers, generally equipped with rubber crushing rolls and used as an attachment to a mowing machine, do little more than flatten out a grass stem and crush the nodes. Such moisture as may be mechanically forced out of the grass by the rolls has little opportunity to drain away from the mass. There is ample evidence that the hay-crusher has many advantages under favorable hay-making conditions but such a unit has little value when the sky is overcast and the soil is filled with moisture.

Outline of Tests

This report covers the mechanical dewatering of a number of chopped forage crop materials thru the use of a No. 10 Vincent tomato pulp screw press with an air cushioned cone choke. The principal objective of the study was to determine what portion of the moisture, that has been designated as the "A" phase in Figure 4, could be mechanically removed. Trade journals and other sources of information have been found to report only one instance where mechanical dewatering has been applied to forage crops, and that was to obtain alfalfa press liquors for pharmaceutical use.

The experience of the authors gained in the mechanical dewatering of sweet potatoes, citrus by-products and other industrial wastes suggested the possibility of applying the screw press to chopped forage materials over other forms of equipment designed to use mechanical pressure. Figure 5 shows a screw press in partial section. This shows that the screw or auger does not extend in a continuous section from the feeding hopper to the adjustable cone that closes off the outlet from the screen appearing as a shell or cylinder about the auger. The support for the shell contains cutoff blades that enter into the work area, thus increasing the squeezing and crushing action of the unit. A temporary installation of the Vincent press at the Everglades Experiment Station is shown in Figures 6 and 7 during operation. The flow of liquor from the press may be noted in Figure 8. The liquid flowing from a six inch roof eave gutter section represents the discharge of press liquors from overaged alfalfa as fed into the hopper by one man at at an easy feeding rate with a five-tine pitch fork.

The chopped forage materials used in these investigations were supplied by Bel-Vita Farms, Inc., Belle Glade, and by the Agronomy Division of the Everglades Experiment Station. In either instance it was prepared through the use of a forage crop harvester set to give a ¾ inch cut.

RESULTS

The tests covered in this report include the direct mechanical dewatering of 22 different lots of the chopped forage materials used in full capacity feeding to the Vincent press. The reference to direct mechanical dewatering is of particular significance because the same method used in other applications requires supplemental processing and the addition of certain chemicals to make application of the press possible.

Representative data obtained from the mechanical dewatering of chopped forage materials are shown in Figure 9. The moisture removed from each sample by mechanical dewatering is indicated by an arrowed line leading down to a line representing the amount of moisture in the press cake.

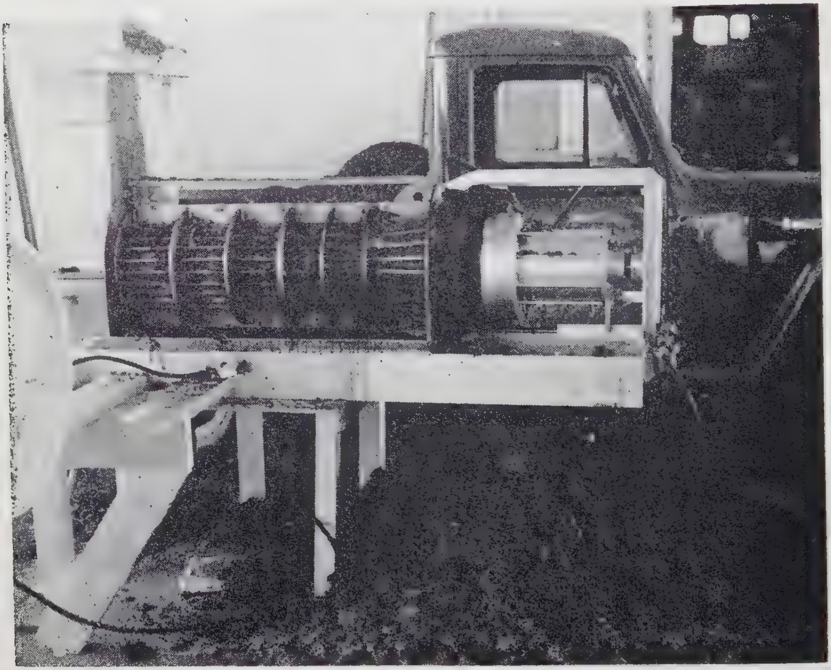

Figure 7.—Side view of Vincent press with cover removed to show strongly ribbed filter screen shell. Note accumulation of press cake on floor at discharge point below "choke" assembly on right.

The chopped Para grass samples 1A and 1B represented a succulent growth produced under very favorable conditions of culture on Everglades peat. The only difference between these adjacent harvests was the time of day at which they were taken. Samples 1-A, harvested at 7:00 A.M., was well covered with dew whereas 1-B, taken at 3:00 P.M., showed some indication of wilting due to field heat at that time of day. Attention is called to the moisture in the resultant press cake from the two lots.

The difference in the amount of water it was necessary to evaporate from the two lots of Para grass referred to above to produce a ton of finished feed was found to be as follows:

Time of Harvest	*Moisture Content* *Fresh Grass*	*Press Cake*
7 A.M.	13,010 pounds	4,100 pounds
3 P.M.	7,170 pounds	4,020 pounds

The same general data applied to the total dry matter intake of a cow eating 50 pounds of each of the green forages represented would be as follows:

Time of Feeding on Para Grass	Dry Matter in 50 Pounds Fresh Grass	Press Cake
7 A.M.	5.99 pounds	14.35 pounds
3 P.M.	9.81 pounds	14.94 pounds

An attempt was made to simulate conditions produced by a heavy rain on a load of chopped green materials. This was Lot 1-BB, otherwise the same as 1-B. The overnight storage and resultant drainage decreased the moisture content of the dewatered meal to 3,370 pounds of water remaining per ton of finished dehydrated material. Similar green material stored overnight without addition of extra moisture was mechanically dewatered to a content of 2,950 pounds of water in undried meal equivalent to 1 ton of dried feed.

Figure 8.—Liquid discharging from Vincent press during operation through a 6-inch gutter section into a shallow ditch. Note thick cap of foam formed through a comparatively brief period of operation.

Equipment was not available to complete this experimental study by artificial dehydration of the dewatered meals thru the use of heated air. The physical condition that was developed in the press cake gave all indications that there would be little difficulty in its direct drying in a drum-type dehydrator. These data on Para grass and other Everglades forages of high moisture content are considered ample evidence that a suitable system of artificial dehydration, into which mechanical dewatering is incorporated, can be carried on for days in an around-the-clock operation.

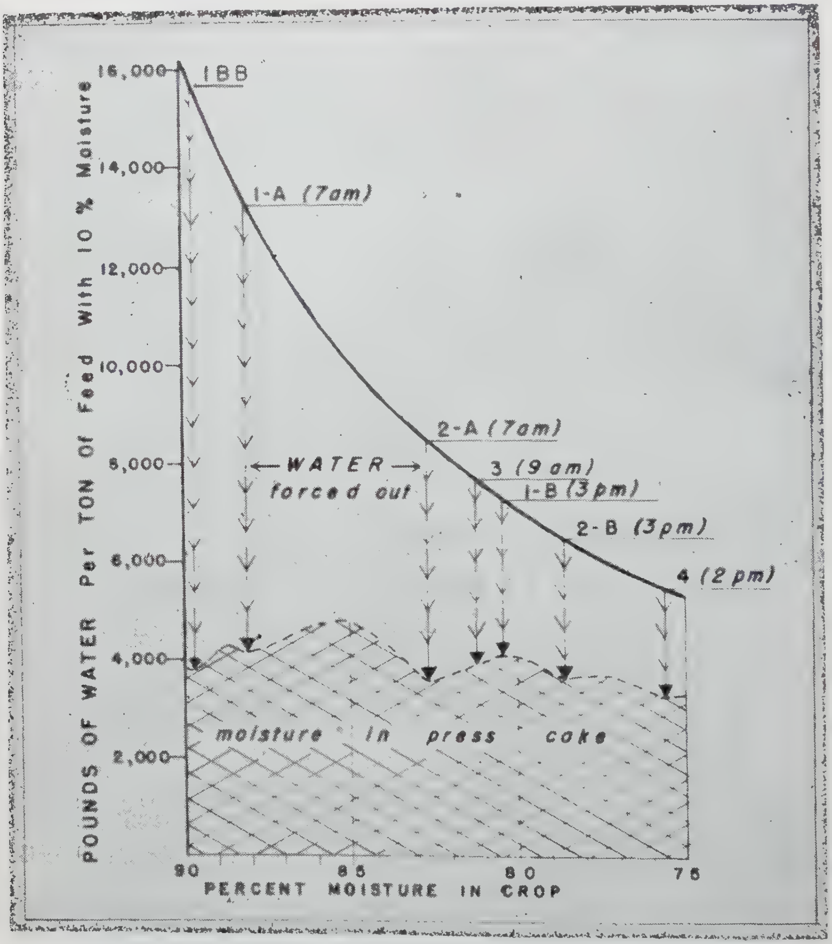

Figure 9.—The effect of mechanical dewatering in removing free water from forage plants prior to dehydration through the use of a No. 10 Vincent press.

1—A and B Para grass
2—A and B Alfalfa
3—Carib grass
4—Panfiola grass
1—BB same as 1—B wet down and stored overnight (18 hours)

The over-mature alfalfa samples, 2A and 2B, show relatively less difference in the original moisture content and the degree of mechanical dewatering when compared to Para grass. However, the two harvests were made on different days and under circumstances which did not bring the early morning alfalfa harvest into serious exposure to dew.

Partial chemical analyses were made by Dr. J. P. Winfree on the original and the processed parts of the forage samples. However, the limited number of data available makes it advisable to hold this phase of the discussion to generalities. Mechanical dewatering is a separating operation in which a screen holds back solids in the buildup of a press cake and permits the drainage of liquid, usually containing more or less solids, that have been forced through the screen. The losses in press liquors represent between 3 and 5 percent solids which include valuable nutrient ingredients both organic and inorganic. However, the value of these remains to be determined.

SUMMARY

Mechanical dewatering of Florida forages as an aid to artificial dehydration gives promise of accelerating interest in the production of dry feeds and even in the direct feeding of undried press cake in tropical and subtropical regions.

The percentage loss of essential nutrients in press liquors is probably minor compared to current losses in hay-making. However, should mechanical dewatering become a farm practice, it may be desirable to make use of the press liquor. This is a consideration that shall have to be determined on the basis of its merit as shown by chemical analysis and by the feasibility of its collection in large volumes according to the manner in which the operation is developed and handled in the future. In the meantime, it might prove entirely practical for the small or individual grower to mount a dewatering unit on a field harvester and waste the expressed plant liquors to the ground, as and where produced.

A Survey of Rice Culture on Organic Soils

Victor E. Green, Jr.*

ABSTRACT

To encourage international cooperation in the study of organic soils for rice culture, a survey was made of the world literature on that subject. With increasing populations and shortages of land for rice culture, it has been necessary in many cases to grow the crop on organic soils in attempts to increase production.

Reclaiming these soils has been difficult and has presented unique problems in soil chemistry. On the one hand are very acid peats wherein iron is reduced to toxic compounds. This condition is found in Sierra Leone, Nigeria, and in Indonesia where it is termed "Hampa". On the other hand are slightly acid to neutral peats wherein iron is in short supply due to reasons outlined, and rice crops are benefitted by additions of iron salts or soil containing large amounts of iron oxides. This condition prevails in Japan and is termed "Akiochi". It occurs also in the U.S.A. in the Everglades on soils derived from sawgrass.

These and other problems encountered where peat soils are used for rice culture are compared and contrasted. The advantages and disadvantages of the soils are discussed, and the benefits that accrue from growing rice on these soils are listed.
A fairly complete bibliography is included.

In the present struggle among world powers, rice has a position of strategic importance as a food material in short supply. In 1950 only a few countries in the Far East grew rice in sufficient quantity for export. These included Korea, French Indochina, Burma and Thailand. The Communists have concentrated their efforts on these lands in an attempt to gain control of the surplus rice for use in appeasing the hunger of overrun nations. The fate of North Korea and Indochina is well known.

Although record rice crops are produced nearly every year, the steadily increasing populations consume all that can be grown. Since most of the arable land of the Far East is under cultivation steps have been taken recently to include the heretofore neglected peaty swamplands in the rice acreage. Reclaiming these soils and growing rice on them have been very difficult tasks. The areas present many difficult problems to engineers, agronomists and pathologists.

The purpose of this paper is to bring together the significant findings, to compare the problems encountered in various localities, to present the advantages of organic soil as a medium for rice culture, to list advantages that accrue from growing rice on organic soils and to include a fairly complete bibliography on these subjects.

BIBLIOGRAPHIES

Only six bibliographies on rice culture are known to this writer. The earliest was prepared by Kondo *et al.* in Japan and is titled "Literatur-Verzeichnis Uber Reis und Reiskultur. Parts I, II and III," and appeared in the Ber. Ohara Inst. 5: 325-346; 7: 575-594; and 8: 489-505 between 1932 and 1941.

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Next to be published was a work in the Netherlands East Indies by Kuilman, entitled "Rice During and After the War," Communication 87 of the General Agricultural Research Station at Buitenzorg, Java. Work done in the years 1940-47 is covered.

Verdoorn compiled a card index to complement this work for use in the East Indies after World War II. The compilation was temporarily housed at the office of the Board for the Netherlands Indies, Surinam and Curacao at 10 Rockefeller Plaza, New York. Its present location is not known by this writer.

In 1951, Ignatieff compiled a mimeographed booklet for the Food and Agriculture Organization of the United Nations entitled "Results of Experiments and Practical Experience in the Use of Fertilizers, Manures and Soil Amendments with Rice"(29).

Jacks and Milne prepared an annotated bibliography from a card index maintained by the British Commonwealth Bureau of Soil Science. This was a joint release by that Bureau and the FAO-UN in August 1954 entitled "An Annotated Bibliography of Rice Soils and Fertilizers."

Those interested in the diseases of rice can consult the work of the U.S.D.A. Plant Disease Survey, "A List of References to Diseases of Rice", Special Publication Number 6, April 30, 1954, by William W. Diehl.

The above-mentioned works as well as abstracting journals were drawn on heavily for the material presented here.

LOCALITIES AND SOIL CHARACTERISTICS

In general the literature indicates that rice culture is more difficult on organic soils than on mineral soils.

The general feeling that rice grows most easily on mineral soils was brought out by Huet (28) who wrote that "healthy" rice soils contain less than 10 percent organic matter. Coulter(6,7,8) discourages the use of peat soils in Malaya and Kratochvil(35) stated that drained marsh land in Czechoslovakia is excellent for rice, provided there is no peat in the soil.

From Europe, there have been reports of rice culture on peat soils in Italy, Czechoslovakia and Russia(3,13,35,44).

TABLE 1.—Chemical Composition of Some Everglades Soils. Percent, 0-12 Inches, Oven Dry Basis.

Composition, %, Oven Dry Basis, Average	Soil Type and Local Name		
	Okeechobee Muck (Custard Apple)	Okeelanta Peaty Muck (Willow & Elder)	Everglades Peat (Sawgrass)
N	1.5	2.7	2.8
P_2O_5	0.5	0.4	0.4
K_2O	0.05	0.05	0.04
CaO	3.8	5.3	5.2
MgO	0.09	0.13	0.10
SiO_2	35.8	9.9	4.2
Fe_2O_3	5.0	1.8	1.0
Al_2O_3	5.1	0.8	0.3

In Brazil, Setzer(16) reported a brief study of a peat soil for rice culture.

In the United States rice research on organic soils has been carried on at the Everglades Experiment Station, Belle Glade, Florida. The average chemical composition of soils there is shown in Table 1.

In Asia, rice is grown on peat soils in a number of areas(30,43). Table 2 shows the chemical composition and properties of a typical peat soil in the Ishikari district of Hakkaido in Japan(32).

TABLE 2.—Chemical Composition of 10% HCl-Soluble Matter, Carbon and Nitrogen Content and Some Important Chemical Properties of a Hakkaido Peat Soil.

Insoluble matter	80.84 %	Carbon and Nitrogen Content (Air dry basis), %	
HCl-Soluble SiO_2	0.032		
Na_2CO_3 Soluble SiO_2	8.57		
Total SiO_2	8.60	Ignition Loss	24.95
Fe_2O_3	5.34	Nitrogen	0.74
Al_2O_3	6.66	Carbon	11.43
CaO	0.48	C: N	15:8
MgO	0.28	pH	6.58
K_2O	0.10	B.E.C.	23.7 m.e.
MnO_2	1.32		
P_2O_5	0.39		

The Imamachi A soil in Niigata Prefecture of Japan has a peat layer in the subsoil. It will be considered below because of the similarity of a nutritional disease present in that area to one found in the Everglades of Florida. The Imamachi A soil is a dark brown clay with a pH value of 4.90; exchangeable CaO of 0.41; exchangeable acidity of 14.50; organic matter, 12:30; free Fe_2O_3, 1.60; total Fe_2O_3, 4.80; and total SiO_2, 16.11 percent, respectively. This soil becomes highly reductive under the high summer temperatures. In this soil, there is an excess of organic matter and a shortage of active iron(31).

Kamashita(34) has prepared a study with special reference to ground water soil types as a preliminary to classifying waterlogged soils in the field. Included are bogs and half-bogs. The chemical composition of each horizon of all soils is given for Japan.

In Ceylon the low-lying acid peats (pH 4.7) associated with paddy soils and characterized by the presence of excessive moisture do not occupy extensive areas(29). The peat is overlaid by a layer of mineral soil 30 to 90 cm. deep. The analysis of air-dried peat showed that it contained 60 percent organic matter, 0.8 percent nitrogen, 1.7 percent CaO and 0.1 percent P_2O_5 and was suited only for rice cultivation. Addition of 1,000 pounds per acre of lime once every three years was found to be beneficial(53).

The peaty and marshy soils of India have a high organic matter content and may also contain large quantities of soluble salts. The extent and nature of these soils are not know; a survey will be necessary for their reclamation and proper utilization.

In Africa most of the research has been done in the West Coastal countries—Angola, Nigeria and Sierra Leone. The organic soils in

Nigeria were reclaimed from mangrove swamp having pH values averaging 5.6. Upon flooding, these soils become increasingly acid over a 12-week period. The average pH value was 1.83.

The complete scheme of rice culture in Sierra Leone has been outlined by Jordan(33) and by Roddan(45). Soil conditions parallel those in Nigeria.

Probably the most important organic soils that support rice growth are in Oceania(17,37,38,39). For an understanding of the soils of this region, readers are referred to the monumental work of E. C. J. Mohr, as translated by Pendelton, "The Soils of Equatorial Regions with Special Reference to the Netherlands East Indies". The use of organic soils for rice was not stressed in this book written between 1933 and 1938. Since that time, however, it has been necessary to crop these soils, and much valuable research work has grown out of the studies carried on at Buitenzorg (Bogor) by Polak, Van Dijk, Van der Spek, Van Wijh, Kuilman, *et al.* It was from this area that Koorders shocked the scientific world in 1895 with the publication that revealed that peat soil could originate outside temperate or cold climates(42).

Peat soils cover one-fifth of the surface of Sumatra, extending along the coasts of Malaya, Borneo and the south coast of New Guinea. They vary in thickness from 0.5 to 16 meters. The deposits are both ombrogenous (formed above water) and topogenous (formed under water). They occur both in the lowlands and highlands. The lime content does not exceed 0.5 percent, and may be as low as 0.14 percent. The ash content is between 1 and 3 percent, phosphate between 0.01 and 0.09 percent and potash between 0.02 and 0.2 percent. The pH value is between 3.0 and 4.5.

The Rawah Lakbok(65), a topogenous peat marsh, has peat 6 meters in depth, with a pH value between 5.4 and 6.0; ash content of 9-10 percent; calcium, about 2 percent; potassium, about 0.15 percent; and phosphorus, about 0.1 percent.

PROBLEMS IN ORGANIC SOIL RICE CULTURE

The problems encountered in the growth of rice on peat soils have been many and difficult. They may be divided for convenience into the following categories: (1) problems in reclamation and water control; (2) problems in diking, and seepage due to the depth to the hardpan; (3) greater severity of diseases than when grown on mineral soil; (4) tendency of plants to lodge under high nitrogen consumption; (5) toxic substances in the water used for irrigation; and (6) nutritional disorders due to the chemical content of the peat, including both deficiencies and toxicities of certain compounds.

Problems in Reclamation and Water Control. In Malaya, another area experiencing a shortage of rice, work has been reported(1,2,5,6,7,8,-9,11,25,26,27,47), much of which has been concerned with mechanical difficulties of land clearing and wet cultivation. There are many submerged logs in the newly reclaimed peat that must be removed when they appear at the soil surface. There is heavy off-season growth of tough sedges and grasses on the peat soils that require special tillage tools.

Problems in Diking and Seepage Due to the Depth to the Hardpan. In the Everglades, rice culture is easiest where marl roads surround the paddies, and are above the elevation of the land. Cross dikes are difficult to maintain unless specifically built with bulldozers, packed well, and planted.

In Indonesia, dikes built from acid subsoil must often be allowed time for toxic substances to leach from them so that adjacent plants will not be killed(54).

Vertical and lateral seepage are great in organic soils, and it is difficult to keep small areas inundated.

Diseases of Rice Grown on Organic Soil. There have been no unique diseases of rice reported because of its culture on organic soil. However, epiphytotics of the more common diseases have been recorded in all stages of growth from tillering to maturity. These include both leaf and neck blast caused by *Piricularia oryzae* Cav.(36) and brown spot disease of both leaves and glumes caused by *Helminthosporium oryzae* Breda de Haan. The high content of nitrogen in the peat soil is thought to be responsible for the severity of the diseases.

Lodging of Rice Plants on Organic Soil. The falling over of headed plants is a serious problem that seems to be due to the extra height and top-heaviness caused by luxuriant growth of certain varieties on the high-nitrogen organic soils. Lodging of plants in the milk stage of grain formation leads to excessive chaffiness, while lodging in the dough stages, when the plants fall into flood water, leads either to germination or decomposition of the grain. It has not been possible to prevent lodging either by the additions of potash to offset ntirogen excess or by withholding irrigation water. Plants in outside rows do not tend to lodge, nor do those in inside rows that are spaced more than four feet apart. The effects on yield of wide spacing of rows have not been fully investigated. Lodging assumes major importance where crops are mechanically harvested, as in the Everglades.

Quality of the Water Used to Irrigate Rice. A review of studies of irrigation waters for rice was prepared by Van Wijh(54) in 1951. He classes the following factors as contributing to the poor quality of water for rice culture, especially on organic soils: "(1) strongly acid reaction due to high contents of iron or aluminum sulfates, or conversely, due to low contents of calcium or magnesium salts, (2) low oxygen content, or low-oxidizing power, and (3) high chloride content." This third factor is common to mineral soil areas also and is mentioned here only because it was in this connection that rice farmers moved into the Everglades to attempt to grow rice on organic soil. Following World War II, a shortage of land in the United States rice belt developed. The price of rice increased and areas in Louisiana and Texas located near the Gulf of Mexico were abandoned as salt water was replacing fresh water in the ground water supply.

Nutritional Disorders. These can be divided into disorders caused by: (1) deficiencies, and (2) toxicities.

In Angola, Pessanha(41) reported a moisture deficiency of rice grown on non-irrigated peat soils. The heaviest grain production was in areas of highest soil moisture and nutrient content. Areas of equally high

nutrient status, but lower soil moisture were characterized by marked floral abortion. Those slightly lower in nutrients gave maximum production where sufficient moisture was available.

Peat soils in the Ishikari district of Japan are low in potassium, and the content decreases markedly at flowering, the time when they most need sufficient potash. Ishizuka and Tanaka wrote that because of the low volume weight of peat and because of the production of methane, rice roots were thought to contact comparatively small amounts of nutrients(32).

Van Wijh(54) reported copper deficiency of rice grown on peat soil in Indonesia. This malady is also called reclamation disease, and "penjakit habang" by the autochthonous people. The disease there, as in the Everglades, is characterized by a rusty-brown discoloration of rice plants. In Florida, the heads do not fill and the leaves have an abnormally dry feel. Here, the disease, for the most part, can be prevented by additions of 50 pounds of copper sulfate or 25 pounds of brown copper oxide per acre prior to planting the first crop on raw sawgrass land, and by including one percent copper oxide annually in fertilizers applied to subsequent crops.

The chief problems in organic soil rice culture are concerned with iron and aluminum, a deficient quantity on the one hand and a toxic quantity on the other. Cause and effect are difficult to separate. The two problems are charaterized below, each being contributory to a "straighthead" condition that results in light, chaffy, and in most cases, empty seed heads.

Hampa = Rapak Disease

This condition of rice failure has been reported and named in Indonesia(54) and has occurred in Nigeria and Sierra Leone on acid, tropical peat soils low in calcium and magnesium, high in iron and aluminum, and containing a high percentage of water-soluble sufate. Some of the peats are underlain by extremely acid clay that is rich in iron and sufides. It contains basic ferric sulfate which is toxic to rice. Van Dijh(12) found clays underlying organic soils in southeast Borneo in 1937 where the native population found it necessary not to turn up much of the acid subsoil in dike building, and was patient enough to permit rainwater to leach the toxic substances before planting in vicinity of dikes. They resorted to controlled peat burning to correct the high acidity. This was a wasteful method, however, since it had to be repeated often to resupply ash leached by the heavy rainfall(54).

Ehrencron suggested the use of lime to decrease the acidity and precipitate the sulfates(16).

Dent reported similar difficulties in Sierra Leone(10). Three factors, either singly or in combination, were found by him to be responsible for partial or total failures of rice on cleared mangrove land: (1) A layer of peat, (2) a high concentration of NaCl and (3) a toxic concentration of iron sulfate coupled with high acidity. The first two were relatively unimportant. The toxic syndrome presented several typical features. The leaves of the rice became rusty in color, the plants were stunted and usually died; the soil became red, and red alga-like growth frequently occurred. The characteristic smell of H_2S sometimes prevailed. Severity of the condition depended somewhat on soil type for Dent found that

toxicity due to iron compounds, as produced in areas of *Avicennia* mangrove soils, seemed to be less lasting than toxicity in *Rhizophora* mangrove soils.

In the Sierra Leone Annual Report of 1949, it was reported that the rice plants were coated with black deposits of FeS below the soil surface. Rice grew well when the soil had a pH above 5.5.

Doyne(14), while working in Nigeria on soils similar to those he had investigated in Sierra Leone, made a laboratory study of the changes in acidity of mangrove soils. When the soil was air dried pH values dropped from 5.6 to 2.5 by two weeks. Soil kept in the moist state showed a steady reduction to pH values between 1.0 and 2.5. His explanation for the increased acidity is shown schematically:

$$\underset{\text{OUS-IDE}}{FeS} \xrightarrow{\text{Oxide}} \underset{\text{OUS-ATE}}{FeSO_4 \cdot H_2O} \xrightarrow{\text{Oxide}} \underset{\text{IC-ATE}}{Fe_2(SO_4)_3} \xrightarrow{\text{Hydr}}$$

$$Fe(OH)_3 \ \underset{\text{ic-Hydroxide}}{(\text{or } Fe_2O_3 \cdot xH_2O)} + H_2SO_4.$$

Van der Spek(48) explained in more detail the formation of the ferric sulfate of the acid clay underlying the peat of Indonesia.[1]

From the standpoint of adding sulfates, it would appear from the statements of Pearsall(63) that ammonium sulfate would be a poor choice of fertilizer nitrogen for such soils as just described. He assumed that $(NH_4)_2SO_4$ produces effects beside those of furnishing nitrogen. The sulfate is reduced to sulfide, and H_2S and methyl sulfide will appear, both producing toxic effects. Ammonia will replace metallic ions in the colloidal complex by base exchange. These bases could then leach away.

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[1] "When there is no free oxygen but easily decomposable organic compounds are present, a reduction of the calcium sulfate washed in by sea water is brought about by bacterial action—

(1) $CaSO_4 + 8H \longrightarrow CaS + 4H_2O$

Under influence of water and carbonic acid liberated by decomposition of organic matter, hydrogen sulfide and calcium carbonate are formed—

(2) $CaS + H_2O \longrightarrow CaCO_3 + H_2S$

The hydrogen sulfide acts immediately on the iron compounds present in the soil, so that ferrous sulfide and elemental sulfur are formed—

(3) $Fe_2O_3 + 3H_2S \longrightarrow 2FeS + S + 3H_2O$

The FeS-S mixture is then very readily converted into iron bisulfide or pyrite—

(4) $FeS + S \longrightarrow FeS_2$

The larger quantities of carbonic acid formed during the decomposition of organic matter effect a dissolution and leaching of the $CaCO_3$ in the marine clay. If this type of soil, in which FeS_2 has been found under anaerobic conditions, is exposed to the air after drainage, the oxygen from the air will oxidize the sulfides. Finally, the FeS_2 is almost entirely converted into ferrous sulfate and sulfuric acid—

(5) $2FeS_2 + 7O_2 + 2H_2O \longrightarrow 2\ FeSO_4 + 2H_2SO_4$

If this oxidation occurs in a soil poor in lime (as in this case), the H_2SO_4 is not neutralized but further oxidation to ferric sulfate takes place—

(6) $2FeSO_4 + 2H_2SO_4 + O \longrightarrow Fe_2\ (SO_4)_3 + H_2SO_4 + H_2O$

Ferric sulfate dissolves slowly in water. By hydrolysis is formed basic ferric sulfate and sulfuric acid by one of the following reactions—

(7a) $Fe_2(SO_4)_3 + 4H_2O \longrightarrow Fe_2(SO_4)_2OH_2 + H_2SO_4 + 2H_2O$ or

(7b) $Fe_2(SO_4)_2OH_2 + 2H_2O \longrightarrow Fe_2(SO_4)(OH)_4 + H_2SO_4$

As sulfuric acid disappears by leaching or otherwise, the hydrolysis proceeds. It may act on base-deficient clay so that aluminum sulfate, and by hydrolysis, aluminum hydroxide may be formed."

This would be accentuated by the acidity resulting from the free sulfate ions. The development of reducing conditions subsequently will not only convert Fe and Mn into the reduced and soluble forms, but will also lead to the appearance of sulfides with possible toxic effects.

The ammonium sulfate could form under natural conditions in rice culture, even if in an evanescent state. The first step would be the formation of ammonia from organic matter decomposition, a process well known to occur.

Then:

$$2NH_3 + H_2S + 2O_2 \rightleftharpoons (NH_4)_2SO_4$$

$$(NH_4)_2SO_4 \left\{ \begin{array}{l} \longrightarrow 2NH_3 \text{ Utilized or in soil solution—Base Exchange} \\ \quad + \qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad \blacktriangledown \\ \longrightarrow H_2SO_4 \text{ to leach Ca and Mg} \qquad \text{Bases Leached} \end{array} \right.$$

It would appear from these considerations that more suitable sources of nitrogen where this element is deficient would be calcium cyanamide, sodium nitrate, nitrate of potash or calcium nitrate.

Akiochi = Iron Deficiency

Akiochi is the Japanese word that names a condition of rice plants growing on soil high in organic matter and H_2S and low in active free iron. The chief differences between Akiochi and the condition previously described (Hampa) are higher pH value and lower iron content in the case of Akiochi. Actually the disease is not caused by deficiency of Fe *per se*, but is probably caused by excess H_2S toxicity. H_2S injures root tissues by inhibition of such respiratory enzymes as cytochromes, and restricts the uptake of nutrients(31).

Early work on this malady was done in Japan. Iri(31) made additional studies. He investigated Imamachi A, a soil that has a peat layer in the subsoil and is a low-productive, wet-rice soil. Extremely high ammonification was found to occur in that soil. But about the same amount of free Fe_2O_3 was found in this soil as in soils producing good yields of rice. The low productive soil became highly reductive under summer temperatures; free H_2S formed in the root zone. This could not be prevented in a field where there is a lack of active, free iron and has excess organic matter. The condition could be corrected by addition of soil with two percent free Fe_2O_3. Iri presented a scheme for the relation of iron and sulfur in the soils he studied.[2]

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[2] A. Normal rice soil—

(Fertilizer $\longrightarrow$) $S^{=} + Fe^{++} \rightleftharpoons FeS \overset{O_2}{\rightleftharpoons} Fe_2O_3$ (No Damage)

It is also quite likely that the FeS could be converted to nutritive ferrous sulfate $FeS + 2\,O_2 \longrightarrow FeSO_4$

B. Low productive soil—

(Akiochi)
(Fertilizer $\longrightarrow$)
(Org. mat. $\longrightarrow$) $\Big\rangle$ $S^{=} + Fe^{++} \rightleftharpoons FeS \underset{\text{No drainage}}{\overset{H_2S}{\rightleftharpoons}} FeS + H_2S$ (Damage)

C. Degraded dry soil—

(Akiochi)
(Fertilizer $\longrightarrow$) $S^{=} + Fe^{++} \rightleftharpoons FeS \overset{H_2S}{\rightleftharpoons} \underset{\text{Drainage}}{FeS + H_2S}$ (Damage)

Literally Akiochi means "fall down". In the later stages of growth, rice affected by Akiochi appears as if it could produce a very good harvest, but there is a falling down in the yield when compared to other fields. When normal wet rice soil yielded 104 to 140 bushels per acre, the low productive, wet rice soil yielded only a 60-bushel per acre crop.

Baba(56), in studies on the "straighthead" condition of rice (empty headedness), related the deficiency of active iron and the amount of ammonia nitrogen in the soil. Where A equals mg NH_4-N/100 g dry soil and B equals mg free Fe_2O_3/g of dry soil, and $A\sqrt{B} > 5$, straighthead is likely to occur. If < 3, straighthead has not been known to occur.

Applying this method to data presented by Iri, it is seen that the formula is valid and helps to explain Akiochi further. See Table 3.

TABLE 3.—THE RELATION OF BABA'S FORMULA TO AKIOCHI ON DATA OF IRI.

Soil Grade	B Free Fe mg./g. Soil	$\sqrt{B}$	A NH_4-N mg./100 g. Soil	$A\sqrt{B}$	Yield Rice, Average Bu./A. Hulled
Low Prod.	16	4	2.95	11.80	60
High Prod.	22	4.7	.78	3.59	124
Normal	18.5	4.32	.78	3.37	120

The data show clearly that there is a relation between a high value and the yield of rice.

THE RELATION OF ORGANIC SOILS AND RICE CULTURE

Organic soils, properly fertilized and under good water control, offer certain advantages for the growth of rice(18,19,20,21,22,23,24,40,49). Foremost is their high nitrogen content. Nitrogen is the most limiting element in world rice production. Rice seems to be a good crop for utilizing low-lying peat soils that cannot be sufficiently drained for other crops, and which would otherwise be wasteland. Organic soils have a high water-holding capacity and can produce crops of rice with a minimum of irrigation from outside sources. Planting as little as 22 pounds of seed per acre in the Everglades has given stands of rice that matured satisfactory crops of grain. Since the peat soils offer the only recourse for expansion in many countries, they permit relocation in areas becoming over-populated.

That organic soils and their environment are benefitted by the culture of rice has been shown by workers at the Everglades Experiment Station from 1951. The findings are reported in the Annual Reports since that date. The flooding in connection with rice culture caused a considerable diminution in the infestation by nematodes to subsequent vegetable crops. Celery roots were free of injury following a rice crop. A bean crop following the celery was relatively free of injury(51,52). The protective effect lasted about one and one-half years. The sclerotia of *Sclerotinia*

sclerotiorum were completely rotted in field soil under the cultural practices employed in lowland rice farming during the summer(50).

Rice culture with its attendant flood water during the summer seems to be very effective in slowing down subsidence of peat soils that oxidize very rapidly in tropical zones.

CHEMICAL STUDIES AT BELLE GLADE, FLORIDA

The history of rice culture in Florida has been published by Green and Stoner(24,19). The crop has been grown on organic soil only in the vicinity of Belle Glade to any extent. The chemical composition of the three main types of peat in this area were given in Table 1. Some of the physical characteristics of the soils are given in Table 4.

TABLE 4.—SOME PHYSICAL CHARACTERISTICS OF EVERGLADES SOILS, 0-12 INCHES OVEN-DRY BASIS, 1929.*

Physical Characteristic, Average	Soil Type and Local Name		
	Okeechobee Muck (Custard Apple)	Okeelanta Peaty Muck (Willow & Elder	Everglades Peat (Sawgrass)
Specific gravity	1.60	1.29	1.27
Hygroscopic water	12.25	15.85	16.47
Capillary water	223.8	336.5	382.9
Loss on Ignition	44.5	80.2	87.1
Ash Content	55.5	19.8	12.9
Reaction	Acid	Sl. A-Neut.	Sl. A-Neut.

* Data of Hammar(59).

These analyses were made in 1929 by Hammar(59). Since that time subsidence has reduced the mass of these soils considerably (about 33 percent) and has lowered the elevation of the soil surface by about three and one-half feet. This has resulted in an increase in the percentage of the chemical constituents, and an increase in specific gravity and ash percentage. The pH values have shown slight decreases despite the accumulation of bases and the movement of the soil surface nearer to the underlying marl rock.

The custard apple soils contain about 16 times as much aluminum, 8 times as much silicon and 5 times as much iron as do the sawgrass soils. The custard apple soils are usually black, contain very little of the original undecomposed plant fibers, are hard and granular when dry and plastic when wet. The sawgrass soils are usually brown, contain many of the original fibers, and are soft and loose at all moisture contents. Phosphorus fixation occurs readily on the custard apple soils, but is no problem on sawgrass soils.

It is with the sawgrass soils that the problem of growing rice has occurred in the Everglades. There is no record of failure of rice due to soil problems on the custard apple soils near the lake shore. New farmers that came into this area in 1951 grew rice on sawgrass soils be-

cause of an abundance of this land at low rental prices. Numerous crops of vegetables were grown before rice was planted and the soil flooded.

In February 1951, one hundred and sixty acres of rice were planted about 15 miles east of Belle Glade on old vegetable land. The seed germinated well, but after a week the seedlings were unusually yellow. The soil was flooded and the water was allowed to drain downwards. This operation tended to aggravate the condition. Plant specimens taken for laboratory examinations showed a brown discoloration of the radicle, but microscopic examination did not disclose the presence of unusual pathogens in the tissues. Plants placed in damp chambers did not produce colonies. When the plants in the field were four to five inches tall growth ceased and the leaves began to turn white. New leaf growth failed to develop.

Field histories showed that large quantities of arsenicals had been applied to previous crops. Iron had never been included in the minor element mixtures on these soils. Water used to irrigate the fields was very high in dissolved $CaCO_3$, which might render most of the iron unavailable. Quantitative analyses of the soil showed that there were only small amounts of arsenic present, the highest figure being 0.45 pounds per acre 6 inches. Rice growth and yield can be seriously affected by the presence of arsenic in quantities not discernible by chemical means.

Preliminary field trials showed that the poor condition of the plants could be corrected by a spray application of ferric tartrate or ferrous sulfate. Soil applications of ferrous sulfate were effective only if applied prior to seeding. With increasing amounts of $FeSO_4$ up to 1,000 pounds per acre, heading was induced and accelerated. Plants receiving the most iron matured first. Plants that did not receive iron suffered from severe straighthead and did not set seed.

A trial in which various treatments were applied with a fertilizer distributor in strips across a quarter-mile wide field was laid out in July 1951. Treatments were as follows:

1. $(NH_4)_2SO_4$, 330* + 0-8-16, 200
2. $FeSO_4$, 1,000
3. 0-8-16, 200 + $Al_2(SO_4)_3$, 300
4. Check, no treatment.
5. $Al_2(SO_4)_3$, 100 + $MgSO_4$, 200 + $FeSO_4$, 200
6. $NaNO_3$, 300 + 0-8-16, 200
7. $Al_2(SO_4)_3$, 250 + $FeSO_4$, 250
8. 0-8-16, 500
9. $MgSO_4$, 500
10. $NaNO_3$, 100 + 0-8-16, 400
11. Check, no treatment.
12. $(NH_4)_2SO_4$, 100 + 0-8-16, 400
13. $Al_2(SO_4)_3$, 800
14. $FeSO_4$, 500
15. 0-8-16, 200 + $FeSO_4$, 300

Figure 1 shows that the only treatments that induced seed formation were those containing either iron sulfate and/or aluminum sulfate. Heads

* Pounds per acre.

formed but did not fill in the other treatments. Additions of aluminum sulfate to the soil helped to alleviate the condition if added to the soil in about three times the amount of iron. In this case, 800 pounds of aluminum salt was equivalent to 300 pounds of the iron salt.

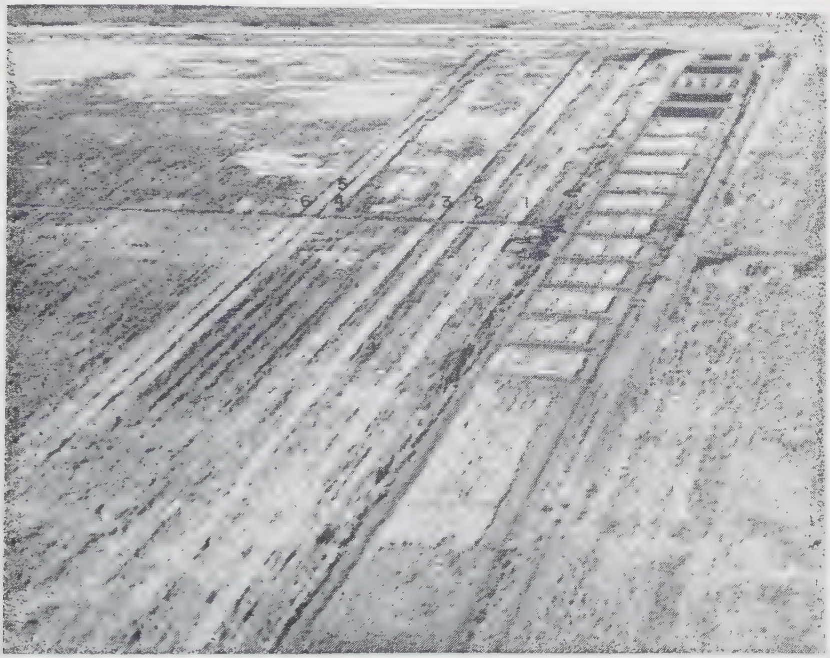

Figure 1.—Aerial of rice field on organic soil. The plants yielded grain only in the numbered strips. Treatments were as follows: (1) Iron sulfate, 1000 lbs./A.; (2) Aluminum sulfate, 100 lbs., Magnesium sulfate, 200 lbs. and Iron sulfate, 200 lbs./A.; (3) Iron sulfate, 250 lbs. and Aluminum sulfate, 250 lbs./A.; (4) Aluminum sulfate, 800 lbs./A.; (5) Iron sulfate, 500 lbs./A.; and (6) Iron sulfate, 300 lbs./A. plus 0-8-16 fertilizer.

There are a number of reasons why iron and aluminum could act as palliatives:

1. That there was a deficiency of active free iron, *per se.*
2. That there were toxic quantities of arsenic present that were converted to insoluble arsenates.
3. That the active free iron in the soil was rendered unavailable by reduction to the sulfide, or was precipitated and carried below the root zone by the flood water highly charged by $CaCO_3$, or was unavailable because it was fixed as the phosphate.

It is conceivable that there was a *per se* iron deficiency. Rice is a heavy feeder on iron, and when soils are flooded the accompanying rise in pH renders much of the iron unavailable. That the malady occurred only on the low iron sawgrass soils would lead to the conclusion of a mere iron deficiency that could be corrected by addition of iron salts.

The symptom was typical of an iron shortage, that is, almost colorless leaves. Iron is seldom added to the soil in the Everglades, but is a necessary component of salt mixtures fed to livestock. Ignatieff(29) reported that the addition of aluminum chloride was very efficient in bringing ferrous iron into solution. He attributed this to either the action of the HCl formed by hydrolysis of the $AlCl_3$ or the greater activity of the aluminum ion.

The extreme toxicity of arsenic to flooded rice growing on organic soil should be obvious. Gile(58) reported that only 4 pounds per acre of arsenic reduced the yield of millet on mineral soil by 50 percent. It is, then, not difficult to understand how infinitesimal amounts of arsenic could cause injury on organic soil which has no clay fraction and very little iron. Flooding the soil aggravates the condition and can lead to the formation of arsine.

Large quantities of arsenicals were added to control insects before the advent of organic insecticides. Iron and aluminum sulfate in excess could form insoluble iron and aluminum arsenates as follows:

$$\underset{}{3\,FeSO_4} + \underset{0.0048g/100\text{ ml. sol.}}{Ca_3(AsO_4)_2} \longrightarrow \underset{\text{Insol.}}{Fe_3\,(AsO_4)_2} + CaSO_4$$

$$Al_2(SO_4)_3 + \underset{0.0048g/100\text{ ml. sol.}}{Ca_3(AsO_4)_2} + 8H_2O \longrightarrow \underset{\text{Insol.}}{2\,AlAsO_4.8H_2O} + 3\,CaSO_4$$

Gile(58) found that the addition of soil containing large amounts of iron reduced the effects of arsenic on millet.

The third possibility is more complex. It is doubtful that the iron could follow the reduction as outlined by Doyne(14) or by Van der Spek(48) since the soils and waters in the Everglades have excess $CaCO_3$. This would make it difficult for formation of carbonic acid required for formation of H_2S from CaS. Likewise, excess H_2SO_4 would likely be converted to $CaSO_4$ and stop the cycle. See Footnote 1.

A complete study of the precipitation of iron in peat soils has been prepared by Puustjarvi(66) in Finland. He has outlined the conditions for the formation and movement of iron as the hydroxide, carbonate, as a colloid, and as the phosphate. A high pH is necessary for the formation of all compounds. When the waters are high in CO_2, the carbonate usually forms. The hydroxide and carbonate are more easily formed than the phosphate.

To ascertain whether an unfavorable phosphorus relationship with iron existed in the muck soils of the Everglades in relation to the growth of rice and whether the symptoms observed in the field experiment could be duplicated in the greenhouse on another soil, phosphoric acid was added to soil in amounts equivalent to 100, 200, 500, 1,000, 2,000, and 5,000 pounds per acre P_2O_5. The plants did not show the symptoms under consideration even at the highest rate, equivalent to 25,000 pounds per acre of 20 percent superphosphate. With increasing phosphorus addition there was increasingly greener color and a longer time required for maturity.

The possibility that the whitening of the leaves might be due to an unfavorable Fe:Mn ratio was investigated. Zero, 100, 200, and 500 pounds

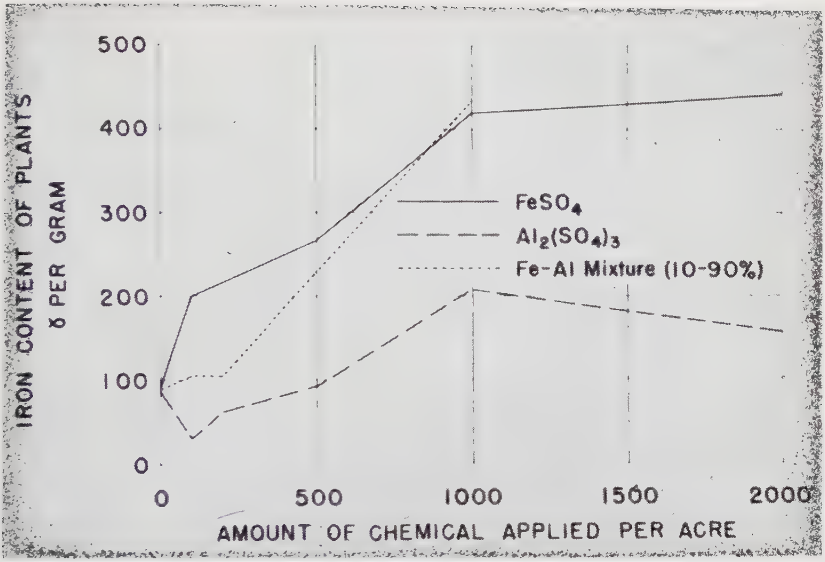

Figure 2.—The Effect of Iron and Aluminum Additions to an Organic Soil on the Uptake of Iron by Rice Plants. Greenhouse, Belle Glade, Florida, 1951.

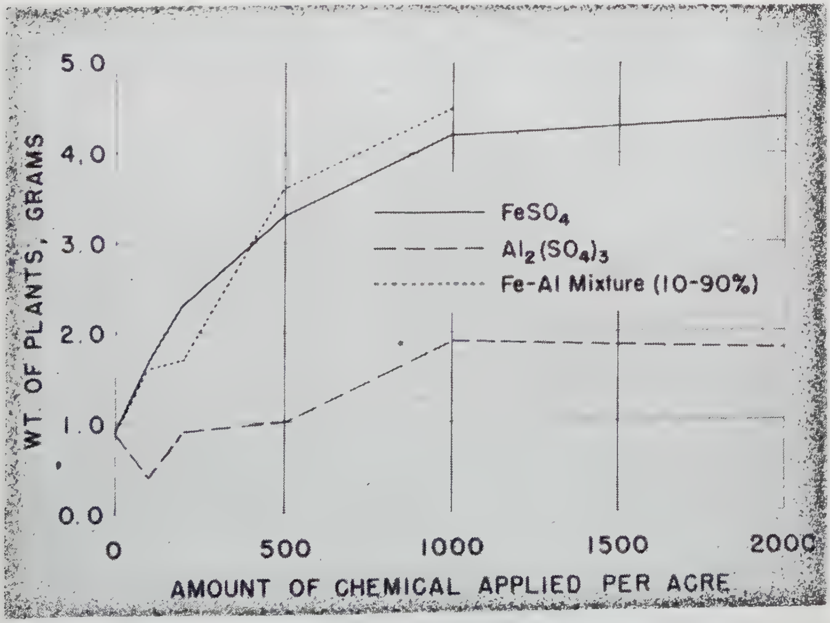

Figure 3.—The Effect of Iron and Aluminum Additions to an Organic Soil on the Yield of Rice Plants. Greenhouse, Belle Glade, Florida, 1951.

per acre of iron sulfate and manganese sulfate were added to soil in all possible combinations. The plants in all treatments grew to maturity without showing the symptoms.

Following the failure of the commercial rice crop east of Belle Glade, a greenhouse experiment was set up to study the effect of additions of iron, aluminum and a mixture of 10 percent iron sulfate and 90 percent aluminum sulfate on the iron contents of rice plants, yields and the ash contents of the plants. The iron contents were determined spectrographically. The data derived from the experiment, conducted in 1951, are shown in Figures 2, 3 and 4. It was shown that the addition of ferrous sulfate in creasing quantities up to 2,000 pounds per acre resulted in increased uptake of iron by the plants, increased yields in grams per pot, and in decreasing percentage of plant ash per gram of dry material.

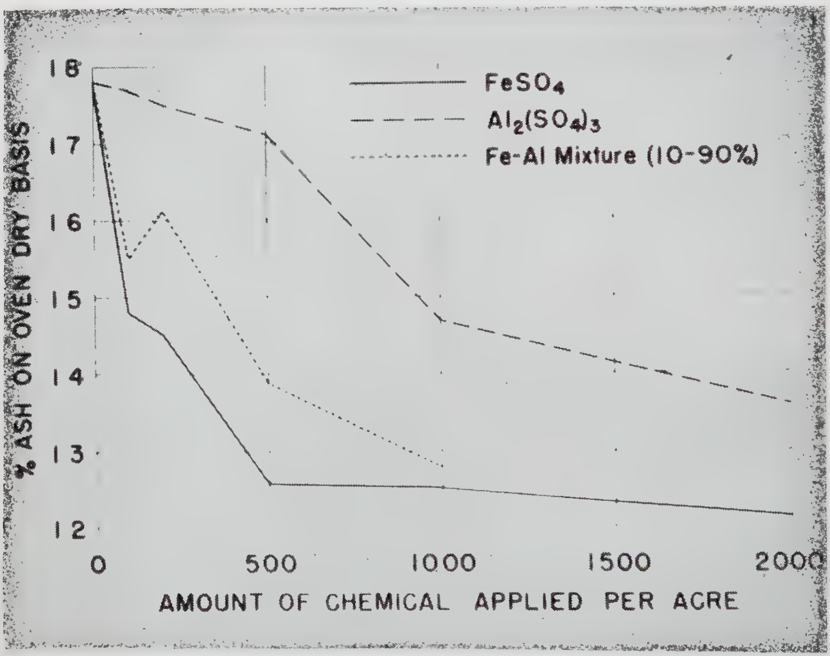

Figure 4.—The Effect of Iron and Aluminum Additions to an Organic Soil on the Percent Ash of Oven Dry Rice Plants. Greenhouse, Belle Glade, Florida, 1951.

Addition of aluminum sulfate resulted in increased yields up to the 1,000 pounds per acre rate and a decreased percentage of ash in the dry plant material. The formation of normal green color in plants was enhanced by addition of aluminum, but uptake of iron by plants was impeded in soil to which aluminum was added at low rates.

Addition of a mixture of iron and aluminum (10-90) resulted in increased yields, lower ash content of dry tissue with higher addition of the salts and in nearly the same uptake of iron as in those treatments where only iron sulfate was added.

Subsequent crops in the field and greenhouse grew well and matured on soils which were treated prior to the first crop of rice.

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Plant Populations, Date of Planting and Nitrogen Levels for Field Corn

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Plant spacing studies and fertilizer experiments with corn were conducted at several locations in north Florida for a number of years prior to 1948. However, when these earlier tests were made, the new corn hybrid varieties now in use were not available. In order to re-evaluate our recommendations for spacing and date of planting corn, preliminary tests to determine the effects of different plant populations and dates of planting on the yield and performance of Dixie 18 hybrid corn were conducted in 1955. In 1956, a more complex experiment, involving nitrogen levels as well as dates and spacings, was begun.

PREVIOUS WORK

Warner, *et al.*(14) report that results of several tests demonstrated little increase in yield, if any, from plant populations higher than 6,000 per acre, regardless of heavy applications of fertilizer. These workers further report that response of corn to side-dressings of more than 40 to 50 pounds of nitrogen per acre is not likely to be either marked or profitable if 10 to 20 pounds of nitrogen is contained in the initial fertilizer application or a good stand of a leguminous cover crop is plowed under prior to planting the corn. Horner and Hull(5) at Gainesville found that, although early corn hybrids produced more grain at 11,500 plants per acre, a full-season hybrid was not benefited by spacings closer than the recommended rate of 6,000 plants per acre. Results of tests conducted by Hutton, Lundy and Robertson(6) indicate that, in general, March or early April plantings, spacing late maturing varieties 22 to 26 inches apart, and, in addition to 500 to 800 pounds per acre of 4-12-12 or equivalent at planting and additional potash and phosphorus when needed, side-dressing with 175 to 200 pounds per acre of ammonium nitrate are best for high yields on West Florida soils. Blue and Robertson(1) reported that, on sandy soils where moisture is a limiting factor, corn should be planted at the rate of 6,000 to 7,000 stalks per acre, with about 300 pounds per acre of a 4-8-6 fertilizer at planting and about 200 pounds of a 15-0-14 fertilizer as a side-dress. Chapman(3) presented data for four years which show that more than 60 pounds of nitrogen as side-dressing is not economical. These data also show that as amount of fertilizer is increased the number of corn plants per acre should be increased. Wallace(12) stated that hybrid corns appear to utilize fertilizer more efficiently than open-pollinated varieties; however, yields of the hybrids were influenced more by close spacings than were the open-pollinated varieties. Wallace(13) also found that side-dressing with 20

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to 120 pounds per acre of nitrogen increased corn yields from 13.1 to 28.9 percent over no-nitrogen treatments; higher rates of nitrogen failed to increase yields.

Workers in other states have reported similar results. A thorough review of early research is given by Richey(10). Thomas(11) and Lang, Pendleton and Dungan(8). More recently, Woodle and Williamon(15), and Krantz(7), Long(9). Duncan(4). Thomas(11). Lang. Pendleton and Dungan(8) and others have shown a much greater effect on grain yield from increased plant populations at high fertility levels than at low fertility levels.

EXPERIMENTAL 1955

Two separate experiments were laid out as complete randomized blocks to determine the effects of different plant populations and dates of planting on the yield and performances of Dixie 18 hybrid corn. Four-row plots, rows 40 feet long and 38 inches apart, with each treatment replicated five times, were used. The area chosen for these tests had been planted to alfalfa for a five-year period prior to the beginning of these experiments. The alfalfa had been heavily limed and an 0-12-12 fertilizer applied annually. In the fall of 1954, the alfalfa was turned under and the field planted to bitter blue lupine. The entire area was fertilized with 500 pounds per acre of 3-12-12 at planting and all corn was side-dressed with 200 pounds per acre of nitrate of soda about three weeks after planting and the same amount about six weeks after planting (79 pounds per acre total nitrogen). Data were taken on the two middle rows of each four-row plot. All plots were cultivated as often as necessary to control weeds. Yields were corrected for variations in stand and adjusted to a 15 percent moisture content.

For the plant population study, plots were planted in 38-inch rows at 6 different spacings to give populations ranging from 4,000 plants per acre, increasing by increments of 1,500, up to 11,500 plants per acre. For each spacing the corn was planted at two different dates, March 1 and April 1.

In the date of planting test, plots were planted at two-week intervals from February 15 to May 1. For each date, the corn was spaced 24 inches (7,000 plants per acre) and 32 inches (5,160 plants per acre) in the hill.

RESULTS AND DISCUSSION

Yields in the plant population experiment showed a highly significant difference between treatments (Table 1). The 4,000 plant population, at both dates of planting, yielded significantly less than the other populations, except for the March 1 planting of 5,500 plants per acre. A further analysis of the treatments showed a highly significant difference between the average yields of the plant populations. The average yield differences between the two dates of planting were not significantly different; however, the trend is for a higher yield from the April 1 planting compared with the March 1 planting. Data given in Table 1 show that, on the average, by increasing the number of corn plants per acre from 4,000 to 5,500 an increase in yield of corn of 9.4 bushels per acre was

TABLE 1.—Average Yield of Corn, in Bushels per Acre, from Plant Population Studies, 1955.

Date of Planting	Plant Population						Average
	4,000	5,500	7,000	8,500	10,000	11,500	
March 1	44.3	48.9	62.3	64.4	58.0	69.3	57.8
April 1	41.6	55.7	64.9	67.5	73.3	69.1	62.0
Average	42.9	52.3	63.6	66.0	65.7	69.2	

L.S.D. for Treatments (5%) 10.4, (1%) 13.9.
L.S.D. for Average of Plant Populations (5%) 7.5, (1%) 10.0.

TABLE 2.—Plant Characteristics as Affected by Plant Population and Date of Planting in 1955.

Treatments		Date 50 Percent Silked	Percent Plants Suckered	Lodging Percent-age	No. Ears per Plant	Wt. per Ear (Lbs.)
Plant Population	Planting Date					
4,000	3-1	5-25	60	1	1.78	0.444
	4-1	6-14	46	1	1.83	0.403
5,500	3-1	5-24	53	2	1.47	0.430
	4-1	6-13	52	1	1.96	0.369
7,000	3-1	5-24	43	2	1.48	0.429
	4-1	6-13	35	2	1.79	0.374
8,500	3-1	5-26	34	2	1.24	0.436
	4-1	6-15	30	3	1.67	0.342
10,000	3-1	5-26	40	1	1.04	0.396
	4-1	6-15	15	4	1.50	0.352
11,500	3-1	5-26	43	2	1.09	0.397
	4-1	6-15	14	3	1.29	0.340

TABLE 3.—Average Yield of Corn, in Bushels per Acre, from Date of Planting Studies, 1955.

Plant Spacing	Date of Planting						Average
	2-15	3-1	3-15	4-1	4-15	5-1	
24 in. (7,000 plants)	45.4	52.8	59.3	60.0	60.7	56.8	55.8
32 in. (5,160 plants)	51.7	51.8	40.7	53.2	51.9	44.0	48.9
Average	48.6	52.3	50.0	56.6	56.3	50.4	

L.S.D. for Treatments (5%) 12.1.
L.S.D. for Average of Plant Spacings (5%) 4.9, (1%) 6.6.

obtained. An additional increase in stand of 1,500 plants per acre to 7,000, gave an increase of 20.7 bushels per acre over the 4,000 rate and 11.3 bushels per acre over the 5,500 rate. These increases are significant. However, as the stand is increased above 7,000 plants, the increase in yield is not significant; an additional 4,500 plants per acre, from 7,000 to 11,500, gave an increased yield of only 5.6 bushels of corn per acre. Thicker stands tended to delay silking two days on the average (Table 2). The percentage of plants suckered was highest for the March 1 planting, compared to that of the April 1 planting; suckering decreased with an increase in stand. On the other hand, the number of ears per plant was larger in the April 1 planting. Number of ears per plant, like suckering, decreased with higher rates of planting. The average weight per ear decreased with both later planting and increased rate of planting.

In the date of planting experiment, as shown in Table 3, yields for all dates at the 24-inch spacing (7,000 plants per acre) were higher, except for the February 15 planting, then for the 32-inch spacing (5,160 plants per acre). For both spacings, between February 15 and April 15 the trend is for increased yields with later planting dates. After April 15 yields decreased with the later date of planting. When comparing plant spacing averages, the same trend exists; however, the yield differences are non-significant. The average yield for the 7,000 plant stand was significantly higher than the average yield for the 5,160 plant stand. Data given in Table 4 show that the number of days from planting to silking decreased considerably with later dates of planting, a difference of 20 days being noted between the first two dates (February 15 and March 1) and the last date (May 1). The percent plants with suckers was lowest for the 7,000 plant population. The average number of ears per plant and the average weight per ear were larger for the 5,160 plant stand than for the 7,000 plant stand.

No significant interaction was found between dates of planting and plant population in either experiment.

EXPERIMENTAL 1956

The experimental procedure was changed in 1956 to include nitrogen levels as well as plant spacings and dates of planting. A new design which has been proposed by Box(2) was selected in order to reduce the number of plots required, and yet allow a response surface to be fitted. Five plant populations and five nitrogen levels were combined into nine different combination treatments; three plantings were made, at three-week intervals, beginning March 1. Each plot consisted of six rows, 18 feet long and 38 inches apart; the four middle rows were harvested for yield. All treatments were replicated three times. The field was planted to bitter blue lupine in the fall of 1955 and turned under in the spring of 1956. The entire area was limed with one ton of dolomite per acre prior to planting. At planting, 1,400 pounds per acre of 0-10-20 fertilizer plus minors in the form of fritted trace elements with additional zinc were applied. One-fourth of each nitrogen level also was added at this time. The remaining nitrogen was applied as follows: one-fourth when corn was knee-high, one-fourth when corn was chest-high, and one-fourth when corn was at the pre-tasselling stage of growth. Following each

TABLE 4.—PLANT CHARACTERISTICS AS AFFECTED BY DATE OF PLANTING AND PLANT SPACINGS IN 1955.

Treatments		No. Days Planting to Silking	Percent Plants Suckered	Lodging Percent-age	No. Ears per Plant	Wt. per Ear (Lbs.)
Planting Date	Plant Spacing					
2-15	24 in.	86	21	4	1.30	0.355
	32 in.	86	28	9	1.56	0.450
3-1	24 in.	86	35	1	1.29	0.416
	32 in.	86	49	2	1.68	0.440
3-15	24 in.	84	19	4	1.51	0.411
	32 in.	84	23	2	1.37	0.410
4-1	24 in	75	33	4	1.70	0.367
	32 in.	75	53	3	1.93	0.384
4-15	24 in.	74	3	7	1.57	0.382
	32 in.	73	8	2	1.69	0.426
5-1	24 in.	66	5	1	1.54	0.352
	32 in.	66	14	0	1.67	0.367

TABLE 5.—COMBINED ANALYSIS OF VARIANCE OF CORN YIELDS, 1956.

Source of Variation	D. F.	Mean Squares
Replications	2	3,107
Dates	2	17,377**
Error (a)	4	838
Combinations	8	1,871**
Combination x Dates	16	213
Error (b)	48	349

** Significant at the 1% level of probability.

TABLE 6.—AVERAGE YIELDS OF CORN, 1956.

Combinations		Average Yield		Date of Planting		
Population Plants/Acre	Nitrogen Lbs./Acre	Actual Bu./Acre	Calcu-lated* Bu./Acre	March 1 Bu./Acre	March 23 Bu./Acre	April 15 Bu./Acre
5,000	160	51	53	70	48	36
7,000	100	62	62	80	67	40
7,000	220	63	59	75	63	51
9,000	40	64	63	79	70	41
9,000	160	66	68	72	75	51
9,000	280	70	73	87	72	52
11,000	100	69	70	85	76	47
11,000	220	84	82	109	79	65
13,000	160	83	83	106	84	58
Average				84.8	70.2	49.2

L.S.D. for Average Dates of Planting (5%) 15.5, (1%) 25.7.

* Calculated from Regression Surface (Figure 1).

planting, the plots were irrigated with one-half inch of water to insure a better germination and stand of plants. The corn was cultivated as often as necessary to control weeds. At harvest, all yields were corrected for variations in stand and adjusted to 15 percent moisture.

RESULTS AND DISCUSSION

The combined analysis of the 1956 experiment shows a highly significant variance for dates (Table 5). Average yield declined as date of planting was delayed after March 1, the sharpest decline resulting between the last two dates (Table 6). The highest yield, 109 bushels per acre, was obtained with 11,000 plants, 220 pounds of nitrogen and March 1 planting. The yields for respective combinations follow a similar trend in each of the planting dates as evidenced by the non-significant combinations X dates interaction (Table 5).

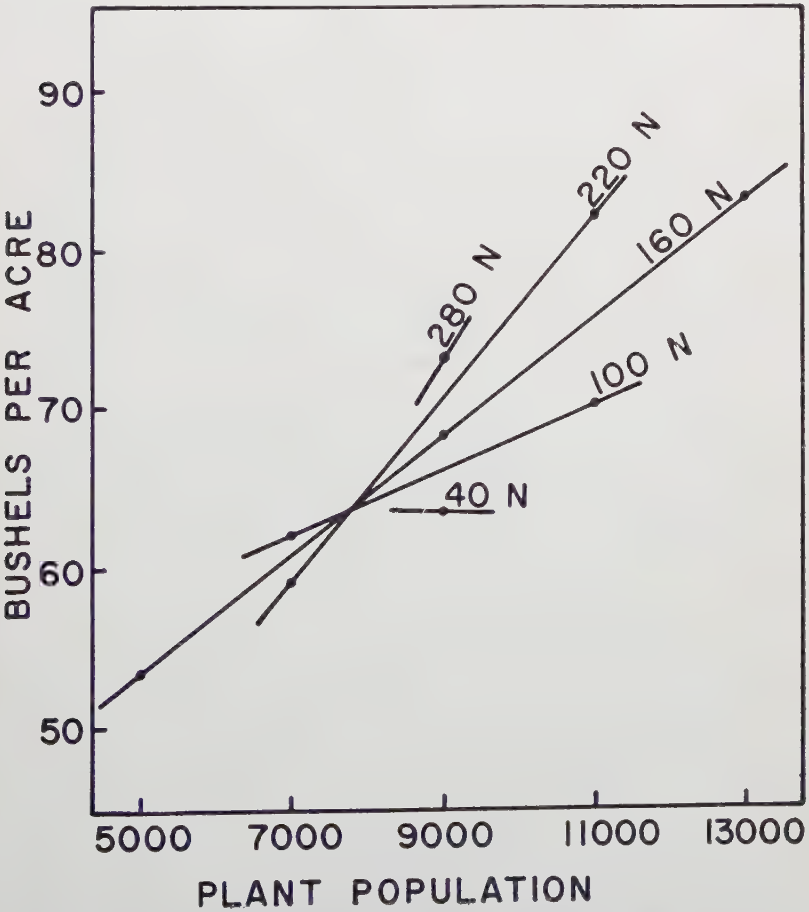

Figure 1.—Effect of plant population on corn yield at different nitrogen levels in 1956.

In the combined analysis of the 1956 data, the variance for combinations is highly significant (Table 5). The analysis of variance for the components of combinations (Table 7) shows a highly significant linear regression for spacing. The linear regression for nitrogen was positive but non-significant, and the interaction of linear nitrogen X linear spacing was similarly non-significant. There was no significant curvilinear regression. Altering the plant population had a greater effect on yield than varying the nitrogen levels. For example, at the intermediate population (9,000 plants per acre) yield was increased only six bushels per acre by a 240-pound per acre increase in nitrogen. In contrast, at the intermediate nitrogen level (160 pounds per acre) an increase from 5,000 to 13,000 plants per acre increased yield by 32 bushels (Table 6). The highest yields were obtained from the two combinations: 11,000 plants with 220 pounds of nitrogen, and 13,000 plants with 160 pounds of nitrogen.

TABLE 7.—Analysis of Variance for Yield Response Surface, 1956.

Source of Variation	D. F.	Mean Squares
Combinations	8	1,871.1*
Linear Nitrogen	1	1,203.6
Linear Spacing	1	12,243.8**
Lin. N x Lin. S	1	938.6
Curvature	2	19.4
Quadratic Nitrogen	1	15.1
Quadratic Spacing	1	15.9
Residual	3	187.9

* Significant at the 5% level of probability.

** Significant at the 1% level of probability.

The effect of plant population on yield of corn at different nitrogen levels, based on calculated yields, is shown in Figure 1. With low nitrogen, increasing the plant population did not raise the yield of corn appreciably. However, at higher nitrogen rates, increases in the number of plants per acre resulted in larger corn yields.

SUMMARY

With a uniform application of 79 pounds of nitrogen per acre, yields of corn in 1955 were not increased significantly by increasing stand over 7,000 plants per acre. The highest yields were obtained from plantings made between March 15 and April 15; earlier or later plantings decreased yields.

In the 1956 experiment, altering the plant population had a greater effect on yield than varying the nitrogen level. With low nitrogen, increasing the plant population did not raise the yield of corn appreciably. At higher nitrogen rates, increases in plant population did result in higher corn yields. The highest yields were obtained at combinations of 11,000 plants with 220 pounds of nitrogen, and 13,000 plants with 160 pounds of nitrogen. Yield declined as date of planting was delayed after March

1. Both the number of ears per plant and the average weight per ear decreased with higher rates of planting.

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BANQUET AND BUSINESS MEETING

The annual business meeting of the Society was held in the Seminole Room of the Fort Harrison Hotel on the evening of November 29 following an after-dinner talk by R. V. Allison, with slides, on the subject "The Future Use of Everglades Lands in Relation to the Conservation and Use of Water." This subject tied in well with the full day of discussion on November 28 that continued on into an evening discussion of Florida water problems on a Statewide basis.

The meeting was called to order by President Ruprecht at 8:45 P.M. and the report of the Secretary-Treasurer on membership, finances and publications made the first matter of business.

MEMBERSHIP

The present status of membership is shown by the usual table on the number and distribution of the different categories that has been prepared for presentation below. As in former years this is on the calendar year basis.

MEMBERSHIP AS OF DECEMBER 31, 1956

	Annual		Sustaining		Honorary Life		Total	
	1955	1956	1955	1956	1955	1956	1955	1956
Florida	661	550	104	97	....	1	765	648
U. S. (other than Florida)	181	171	45	47	8	7	234	225
Caribbean area	128	99	5	7	....	....	133	106
Foreign (other than Caribbean)	36	40	7	8	2	1	45	49
Total	1006	860	161	159	10	9	1177	1028

REPORT OF THE TREASURER

Statement of Receipts and Disbursements
Year Ending December 31, 1956*

RECEIPTS

Cash in bank 12-31-55

Everglades Federal Savings & Loan Co.	$3,750.24	
Florida National Bank	3,204.28	
		$ 6,954.52
Receipts—Dues Collected, Proceedings Sold and Interest Dividend		3,777.41
Total Monies to be Accounted for		$10,731.93

Disbursements

Expenses

Office Supplies	$ 122.07	
Postage	246.00	
Printing—Proceedings Vols. XV, V-B and VI	4,830.05	
Payroll	975.00	
Bank Charges	.52	
Expenses Spring Meeting, Sanford	10.00	
Travel	103.50	
Expenses Annual Meeting, Clearwater	82.98	
Total Expenses		$6,370.12
Cash in Banks 12-31-56		
Everglades Federal Savings & Loan Co.	$3,882.65	
Florida National Bank	479.16	
		4,361.81
Total Monies Accounted for		$10,731.93

* Approved by the Auditing Committee
Dr. Victor E. Green. Chairman

PUBLICATIONS

A total of 1,500 copies of Proceedings Volume XV was published of which 1,262 have been distributed to date.

As a matter of record the following numbers of the earlier Proceedings are available in the Office of the Secretary and can be had, so long as they last, at $1.00 per volume.

I (1939) 74	II (1940) 120	III (1941) O. P.
IV-A (1942) O. P.	IV-B (1942) 150	V-A (1943) 140
V-B (1943) 170 (and)	VI (1944) 170	VII (1945) 375
VIII (1946-7) O. P.	IX (1948-9) 179	X (1950) 110
XI (1951) 32	XII (1952) 125	XIII (1953) 240
XIV (1954) 164	XV (1955) 340	XVI (16)* (1956) in press

* Beginning with Volume 16 arabic numbers will be used.

In the course of organizing Proceedings Volume V-B and VI for the press it was found that an appreciable saving could be effected by joining the two under a single cover. At long last this volume of 272 pages will be mailed to those members qualified to receive it late in January.

As has already been pointed out, the helpful cooperation on the part of those presenting papers on the annual programs in getting their manuscripts ready for publication in good time, together with a substantially improved press service, is enabling earlier publication of the Proceedings each year. It is our hope that this will continue to improve each year.

REPORT OF THE RESOLUTIONS COMMITTEE

A Resolution of Sympathy was read by the Secretary which told of the Society's loss by death of four members, two of them Honorary Life-

time Members. The reading was followed by a brief period of silence at the request of the President. The Resolution is published in full on Page 364 of this volume.

REPORT OF NOMINATING COMMITTEE AND ELCTION OF OFFICERS

The Nominating Committee appointed by President Ruprecht during the first day of the meeting consisted of E. L. Spencer, W. T. Forsee, Jr., and C. M. Ceraldson, with the latter acting as Chairman. At the request of President Ruprecht Dr. Ceraldson reported as the Committee's unanimous choice for nomination as Vice President Dr. George D. Thornton, formerly Soil Microbiologist in the Soils Department and presently Assistant Dean of the College of Agriculture, University of Florida. He also moved that the nominations be closed and the Secretary instructed to cast a unanimous ballot for Dr. Thornton. The motion was seconded and there being no nominations from the floor it was carried by unanimous vote.

With the election of Dr. Thornton as Vice President of the Society Dr. Darrell E. McCloud automatically became President and the gavel was immediately turned over to him by President Ruprecht, who assumed the place as Immediate Past President on the Executive Committee earlier held by Dr. Fred H. Hull.

President McCloud's principal remarks in closing the business meeting pertained to the responsibility of the Vice President for the organization of the program for the coming year and pointed out briefly how something of an ex-officio committee had been developed which has been found exceedingly helpful in that connection. It is made up of the heads of departments in the College of Agriculture interested in the subject matter of the Society along with those in charge of Branch Experiment Stations and field laboratories over the State.

There being no other business to come before the meeting it was declared adjourned at 10:00 P.M. after a call by President McCloud for a brief meeting of the Executive Commitee to follow immediately.

MEETING OF EXECUTIVE COMMITTEE

The meeting of the Executive Committee was called to order by President McCloud who presided as Chairman.

The first order of business was the appointment of R. V. Allison to continue as Secretary-Treasurer.

It was decided that the place of the next meeting would be at Gainesville in Dan McCarty Hall on the campus of the University of Florida, December 4, 5 and 6.

There was a certain amount of discussion regarding the general character of the program desired but no definite decision was taken as to its specific makeup.

The badge for the next meeting also was discussed with considerable favor shown the usual celluloid unit as first tried at the Clearwater meeting on which a rather large printing can be placed through the use of the convention model typewriter.

The time and place of the Spring Meeting that has been under trial for the past three years was discussed. The general feeling was revealed that the usefulness of these meetings has not nearly come up to expectation. Discontinuance was decided upon, at least for the time being.

Attention was called to the fact that there are two vacancies in the Society's group of ten (10) Honorary Lifetime Memberships. It was generally agreed that in the future these appointments should alternate between workers in the Soil and Plant Sciences perhaps with an occasional appointment from a closely related field such as Agricultural Engineering or Animal Husbandry. The decision was unanimous that Dr. H. H. Hume, Dean Emeritus of the College of Agriculture and a horticulturist of national and international repute be the next member invited to join this group.

A full and complete expression of the Society's thanks was voted to the management of Fort Harrison Hotel and to the Convention Bureau members for their efforts at making the meeting such a pleasant and effective experience with instructions to the Secretary that these be included with the acknowledgments published at the front of the Proceedings.

There being no other business to come before the meeting it was declared adjourned by the president at 10:30 P.M.

RESOLUTION OF SYMPATHY

WHEREAS, death has taken from our rolls during the year the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come,

NOW, THEREFORE, BE IT RESOLVED, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

T. R. Drummond
San Juan Capistrano, California

Dr. David Jacobus Hissink
(Honorary Lifetime Member)
Haren, Netherlands

Carl F. Ladeburg
West Palm Beach

Dr. Charles Ernest Millar
(Honorary Lifetime Member)
East Lansing, Michigan

R. W. RUPRECHT

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1956—Retired

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